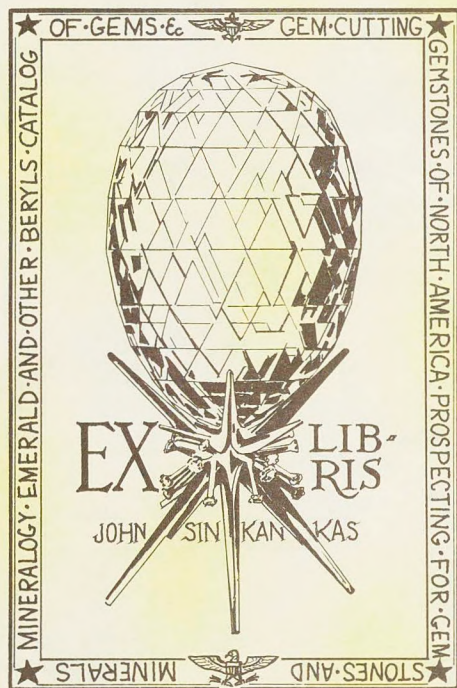


HANDBOOK  
OF  
CORNISH GEOLOGY

BY  
E. H. DAVISON, B.Sc., F.G.S.

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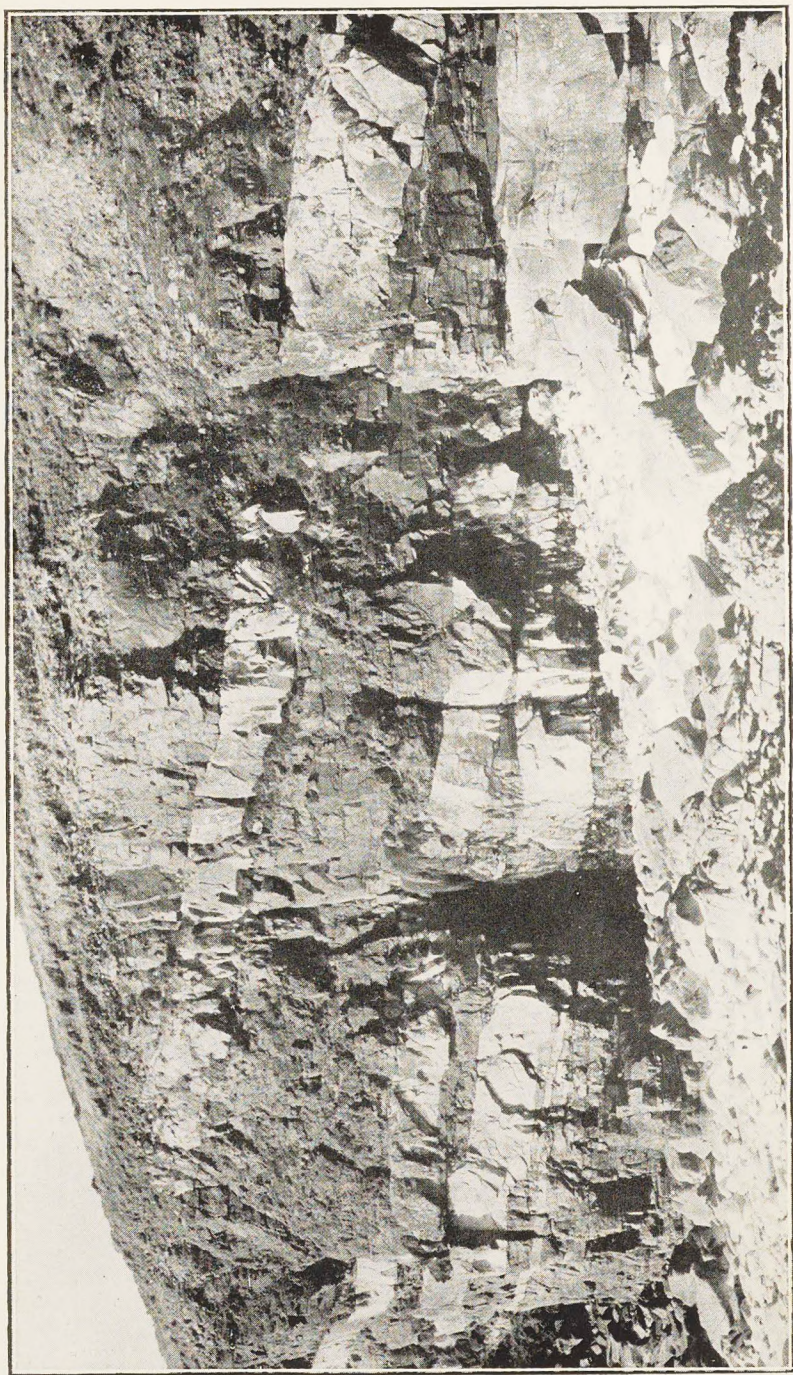
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Photo—H. Preston, Sidmouth.

PEGMATITE VEINS TRAVERSING LOWER DEVONIAN SLATE, MOUNT'S BAY.



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# HANDBOOK OF CORNISH GEOLOGY

BY

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SECOND EDITION.

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TRURO :

Published by Oscar Blackford, Royal Printeries.  
1930.





## P R E F A C E .

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*As no work dealing with the geology of Cornwall as a whole has appeared since Brenton Symons published his book in 1884 it was thought worth while to produce this handbook which is intended to give the reader a general idea of the geology of the County and to indicate the best localities for the study of the various rocks in the field. The book is by no means exhaustive, but it is hoped that it may help the student of Cornish geology and perhaps suggest some of the many fields of investigation which Cornwall offers to the geologist. The author has drawn from many of the books and papers mentioned in the bibliography and trusts that if he has omitted to acknowledge it in the text this general admission will excuse the oversight.*

*The cost of publication has been guaranteed by the Royal Geological Society of Cornwall and the author hopes that his work will be considered worthy of the Society.*

*E. H. D.*

*Camborne, 1926.*

PREFACE TO THE SECOND EDITION.

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*The chief changes in this edition are the revision of Chapters VII., VIII. and IX. and the inclusion of a separate Chapter on China Clay. Several new localities are indicated and the bibliography has been brought up to date. Additional maps and sections have been introduced and the Frontispiece is altered.*

*My thanks are due to Dr. R. H. Rastall for kindly looking through the proofs and to Mr. C. E. Leese for the section of the Camelford district.*

*E. H. D.*

*Camborne, 1930.*



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## INTRODUCTION.

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### THE GEOGRAPHY OF CORNWALL.

---

The county of Cornwall juts out as a long tapering promontory into the Atlantic with a length of about 75 miles and a width at the Devon border of about 36 miles, while between Marazion and Hayle the distance from sea to sea is under four miles. The length of coastline has been variously estimated and, if the coast of every tidal inlet is included, must amount to several hundred miles, sufficient to say it is extraordinarily long in proportion to the area of the county.

The general form of the county is that of an elevated table land, with an average elevation of from 350 to 450 feet, out of which rise a series of hilly moorlands, the chief being Hingston Down with Kit Hill (1,091 feet) near the Devon border, Bodmin Moor with Brown Willy (1,375 feet), Hensbarrow (1,027 feet), Carn Marth (771 feet), Carn Brea (706 feet), Carnmenellis (808 feet), Tregoning Hill (634 feet), and Land's End Moors (805 feet).

The watershed starting within a mile or two of the north coast on the Devon border runs along the line of the moorlands to Brown Willy, then south-west to Hensbarrow and Carnmenellis till it reaches within a mile of the south coast near Germoe, whence it sweeps to the north in a great semicircle and reaches the coast at Land's End.

The highlands for the most part consist of waste moorland covered with gorse, heath and heather and often crowned by granite tors: the soil is peaty and encumbered

by granite boulders, often of great size. The table land is usually well cultivated except where old mine dumps scar the surface; what little timber there is, is of a stunted character with an easterly trend, the result of the strong westerly winds; the fields are mostly pastureland bounded by hedges built of earth and stone, topped by bushes of gorse, blackthorn and other shrubs. Deep narrow valleys have been cut in the tableland and in their shelter timber of good size grows so that the valleys of Lostwithiel, Luxulyan, the River Fal and others are noted beauty spots of the county.

The chief feature of Cornish scenery is however the coastline, which is largely precipitous with cliffs rising to a height of over 300 feet cut by narrow, rocky coves, and here and there broad, sandy bays with an inland border of sand-hills or "towans." The shore slopes steeply, as a rule, some of the cliffs dropping to deep water, while the coastal platform is marked by the presence of numerous stacks varying in size from small islands to mere rocks often standing well out to sea.

The most important islands off the Cornish coast are the Scillies, which, lying about 21 miles west of Land's End, consist of six inhabited islands with many small islets and rocks. The Wolf Rock 10 miles south of Land's End, and the Eddystone nine miles south of Rame Head are instances of stacks exceptionally distant from the coast. The other islands round the coast are little more than large stacks, with the exception of St. Michael's Mount, which is of some size and populated. It can be reached on foot at low tide.

The Cornish rivers are all tidal for some distance from their estuaries, the most important of those flowing to the south coast being the Tamar, Looe, Fowey, Fal and Helford rivers, while at Helston the Cober River is dammed by a shingle bar to form the Looe Pool. The only river



of any size flowing to the north coast is the Camel, which has a long tidal estuary between Wadebridge and Padstow. The Fal estuary forms a safe land-locked harbour and is navigable for big ships as far as Malpas, 12 miles up from the mouth.

The Cornish towns are situated on the coast, at the heads of rivers or in mining areas, Launceston and Bodmin being exceptions to this rule. None are of any great size, the largest having populations varying from 14,000 to 18,000.

Cornwall is traversed by three main roads, the London road which enters the county at Launceston and runs through Bodmin, Redruth and Camborne to Penzance; the Plymouth road which runs from Saltash through Liskeard to Bodmin or by Lostwithiel, St. Austell and Truro to Redruth; and the north coast road which runs from Stratton, through Camelford, Wadebridge and St. Columb a few miles beyond which town it joins the London road. These main roads are connected by numerous cross-roads and branch roads run from the main roads to the coastal towns.

The county is served by two railways; the Great Western which runs from Saltash to Penzance with branches to Looe, Fowey, Wadebridge, Falmouth, Helston and St. Ives, with a loop-line from Par, through Newquay to Chacewater; the Southern Railway serves the north coast, running from Launceston to Wadebridge and Padstow, while Bude is reached by a branch from Halwill in Devon.

There is also an excellent service of motor 'buses so that almost any village can be reached easily.

One of the most pleasant ways of seeing Cornwall is to walk round the coast, which can be followed for almost its entire length by the old coastguards path.

Much has been said of the climate of Cornwall; that it is equable is shown by the growth of sub-tropical plants in almost any sheltered spot. The summers are cool and the winters mild, snow seldom falls and frosts are rare; there is considerable contrast between the climate of the country to the north of the watershed and that to the south, which is much milder. The average annual rainfall is 40 inches which is distributed fairly evenly through the year, long drought being almost unknown. The western part of the county is exposed to the strong winds from the Atlantic Ocean during much of the year but these are usually mild, the cold winds coming from the north and north east in the early spring.



## CHAPTER I.

---

### OUTLINE OF CORNISH GEOLOGY.

---

The County of Cornwall is unique among English counties as regards the geological features it displays. Built up as it is of ancient sedimentary rocks which have been intruded by acid igneous rocks, the phenomena of contact metamorphism and mineralisation are to be seen in great variety.

The foundation of the county consists of Palaeozoic rocks which vary from those of Carboniferous age in the north-east, through Devonian rocks in the centre, to a western series of Lower Palaeozoic age. These have been invaded by dykes and sills of basic igneous rocks which are locally called the Greenstones and are mostly altered dolerites. On the south is a belt of Ordovician strata and, still further south, the Lizard promontory is composed of metamorphosed sediments and a complex series of igneous intrusives whose age is probable Pre-Cambrian.

The sedimentary rocks of Cornwall are predominantly argillaceous and siliceous and the whole assemblage is called Killas by the miner. Lime-bearing rocks are confined to small lenticles of limestone and calcareous slate.

About the close of the Carboniferous period the whole of the area was invaded by an acid magma, which, cooling under a thick cover of sedimentary rock, formed the granite of the district and produced a zone of altered rocks over its uneven surface, while the evolution of solutions and volatile substances brought about the alteration of the granite and the sedimentaries and filled the fissures with mineral constituents to form the lodes.



This period of intrusion was followed by a gap in the geological history of the area, there being practically no rocks of secondary age in the county. It was undoubtedly a period of great wear and tear, during which much of the sedimentary rock cover was removed from the underlying granite, leaving its higher portions exposed at the surface surrounded by a band of contact altered rock of varying width. During the last stages of this period of wear and tear the greater part of Cornwall was below sea level, the granite outcrops forming a group of islands, but toward the end of Pliocene times an elevation of about 400 feet brought the sedimentary rocks well above sea level and gave the county its present form of a slaty table-land from which rise the granite hills.

The Pliocene elevation was followed by a depression of the land and then in Pleistocene times by repeated elevations giving rise to raised beaches round the coast with a final depression in recent geological times which drowned the river estuaries, formed the submerged forests and separated the Scillies from the mainland.

To the pétrologist and mineralogist, Cornwall is a happy hunting ground, the rock types are so varied and numerous and the series of minerals, both metallic and non-metallic, so extensive. The palæontologist will find little to interest him west of Truro and Porthtowan, but east of that line and in the Ordovician rocks of the Lizard and Veyan he will find a fauna well worth his study. An excellent collection of Cornish fossils is to be seen at the Museum of the Royal Geological Society of Cornwall, Penzance.

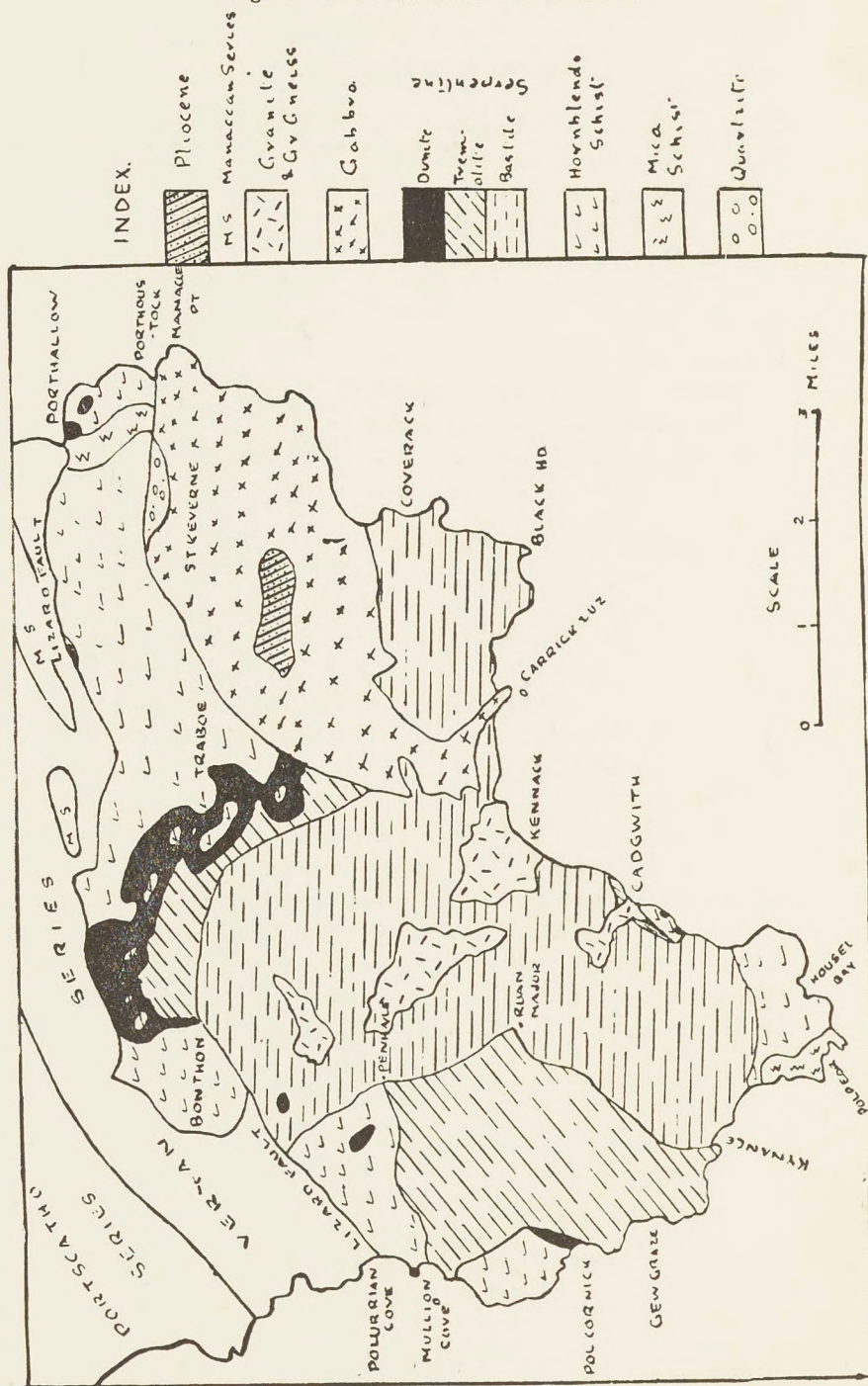
The rocks of Cornwall include the following which are arranged in order of age:—

|                                     |        |                      |
|-------------------------------------|--------|----------------------|
| Alluvium, peat, some head           | ...    | Recent.              |
| Raised beaches, head, stream tin... | ...    | Pleistocene.         |
| Sands, clays and gravels            | ... .. | Pliocene.            |
| "Elvans" or quartz porphyries,      |        |                      |
| aprites and pegmatites, mica        |        |                      |
| traps (?), granite                  | ... .. | Permo-Carboniferous. |



|                                                                                                         |        |                  |
|---------------------------------------------------------------------------------------------------------|--------|------------------|
| Culm measures with basalt                                                                               | ...    | Carboniferous.   |
| Slates, grits, limestones with basic intrusives and volcanics                                           | ... .. | Devonian.        |
| Slates and grits with basic intrusives, the Portscatho, Falmouth and Mylor series                       | ... .. | Lower Palæozoic. |
| Veryan series                                                                                           | ... .. | Ordovician.      |
| Granite, basic dykes, gabbro, serpentine, hornblende gneiss, green schist, mica schist, granulite, etc. | ... .. | Pre-Cambrian.    |

Fig. 1. SKETCH MAP OF LIZARD.





## CHAPTER II.

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### THE METAMORPHIC ROCKS OF THE LIZARD.

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Viewed from a distance, the Lizard promontory appears as a flat table-land some three hundred feet in height with a margin of almost vertical cliffs. This flat character is also very apparent in the southern half of the promontory. This structure is due to the fact that before early Pliocene times the area was subjected to long-continued denudation which culminated in its subsidence below sea level till, in the latter part of the Pliocene period elevation brought it well above sea level as a broad peneplain, the shallow valleys having been incised since that time.

It is an area of great interest to the geologist and in spite of the excellent work of Bonney, Teall, Howard Fox, there are still many problems to solve.

The northern part of the promontory down to a line from Porthallow to Polurrian is built of Palæozoic sediments which can be clearly defined, but to the south the country is formed of a complex of intrusive rocks of predominantly basic character with small areas occupied by highly-altered sediments.

The boundary of this southern area is generally considered to be a fault which can be clearly seen a little to the south of Polurrian Cove, but which is not easily traced across the promontory. The whole of the boundary can however be resolved into segments which are parallel to one or other of the systems of faults,\* while the absence of Lizard rocks from the Devonian conglomerate on the

\* Geol. Survey Memoir, Lizard and Meneage, 1912.

north and the absence of Veryan rocks showing contact metamorphism help to confirm the fault suggestion as being correct.

The age of these metamorphic rocks has been the subject of considerable discussion, there is no means of determining their age with certainty. It has been suggested that they are altered Ordovician rocks, but the north-west strike of the schists is strongly suggestive of their being pre-Cambrian.

The metamorphic rocks in order of age are as follows :

9. Granite and granite gneiss.
8. Kennack gneiss.
7. Dolerite and epidiorite dykes. "Black dykes."
6. Gabbro, augen gabbro, gabbro schist.
5. Troctolite.
4. Serpentine, dunite, tremolite, bastite types.
3. Hornblende gneiss.
2. Treleague quartzite. Tonalite gneiss.
1. Mica schists, green schists, granulites.

The mica schist, green schist and granulite are best seen at Lizard point, being well exposed in Pistil Ogo Cove and Polpeor Cove. The mica schists are highly crumpled and often garnetiferous and include shattered dykes of a basic porphyritic rock. The green schists occur as silky actinolite schists, often intensely folded, including bands and lenticles of epidote. The granulites occur interbedded in the schists and are also found cutting both types. The Man of War rocks consist of tonalite gneiss, an apophysis of which can be seen in the mica schist at the base of Old Lizard Head; pebbles and boulders of this gneiss are of frequent occurrence on the beach. Venton Hill Point is another locality where the schists can be seen well; here the mica schists contain garnet and andalusite as well as a portion of a dyke of ophitic epidiorite.

The Treleague quartzite is another sedimentary rock which occurs near St. Keverne along the edge of the gabbro. The exposures are poor, in small pits and roadside banks.



The hornblende gneiss occurs in four chief areas. On the north they extend from Porthallow to Polurrian; on the east round Cadgwith, at Lizard Point on the south, and Predannack on the west. The rock is usually easily recognised in the field by its rectangular jointing and well-marked foliation. It is composed chiefly of green hornblende and plagioclase felspar with veins and lenticles of green epidosite, pale green pyroxene also occurs in some types which are less clearly foliated than the normal hornblende schist. These schists contain mica schist and granulite, and are infolded with the serpentine, which is supposed to underly the northern area of hornblende gneiss, which shows evidence of having undergone contact metamorphism, being rich in epidote with pyroxene and garnet and having a splintery character.

It was generally agreed that the hornblende gneiss is of igneous origin; its chemical composition indicates this, showing it to have a similar analysis to basalt or dolerite.

Some authorities\* consider that the northern hornblende gneiss is of more recent date than that to the south, but the evidence for this seems incomplete.

Good localities for the study of the hornblende gneiss are Housel Bay to Church Cove; the north side of the valley leading to Mullion Cove; Cadgwith; and the quarry at the bottom of the valley half a mile south of Cury Cross. It is quarried here and there for road metal and is very good material for that purpose.

The serpentine occupies a larger area than any of the other Lizard rocks and gives its distinctive character to the Lizard area. It weathers to a clayey impervious soil and in consequence forms barren moorland over nearly all its inland area. Where it reaches the coast it forms picturesque cliffs and coves, which in the case of Kynance Cove and the Balk are rendered of still greater attractiveness by the varied colours of the rock. The ornamental serpentine of

\*Geol. Survey Memoir, Lizard and Meneage, 1912.



the Lizard is famous, though at the present time it is only worked on the small scale. For the greater part of its northern and southern boundary it is in contact with the hornblende gneiss, while on the eastern side it is penetrated by the gabbro. At its contact with the hornblende gneiss it often shows fluxion banding which is parallel to the foliation of the schist and to the contact of the two rocks: it is infolded with the hornblende gneiss and there is often a band of intermediate character along the contact between the typical forms of the two rocks. Viewing the outcrop of the serpentine from the broad point of view it has a distinctly rounded character and appears to consist of three distinct types with a roughly concentric arrangement.

These three types are as follows:—

The bastite serpentine.

The tremolite serpentine.

The dunite serpentine.

Of these, the Dunite type is the marginal type, a basic differentiation product of the mass. It is a dark green or almost black rock with a conchoidal fracture and a resinous lustre and is often intimately veined with chrysotile and other fibrous serpentines.

The Tremolite type occurs inside the Dunite outcrop and consists of a green or red rock with small pale green crystals of tremolite which are often arranged in parallel layers, giving the rock a fissile character.

The Bastite type or Lherzolute forms the core of the mass, it is characterized by large crystals of bastite (serpentinised rhombic pyroxene) which are plentifully scattered through the rock and easily recognised by their platy cleavage and almost metallic lustre. This is practically the only type of serpentine used for ornamental work, and as a result of oxidation of the constituents its colour is very varied and striking. The working of serpentine is an important industry in the Lizard villages, but no large scale work is now attempted, the quarry once worked at Poltesco



for the manufacture of large blocks and slates having long since closed down, probably owing to the close-jointed character of the rocks, which makes it difficult to obtain large slabs in quantity.

Another variety of serpentine which occurs in all of the above types, but especially the last, is the Chromite serpentine, which is a fine-grained pale green or brown rock without crystals of bastite, but containing black crystals of magnetite, chromite or picotite. A still further type of serpentine occurs along zones of crushing where the rock is converted into a Tremolite schist. The serpentine rock also shows fluxion banding consisting of alternating bands rich in olivine and pyroxene respectively. As the latter do not yield so easily to the action of weathering agents they stand out as ridges on the rock face.

The localities at which the serpentine may be studied are numerous, but the following are some of the most accessible:—

*Dunite Serpentine.*—Quarries on Goonhilly Downs by side of Coverack Road, Traboe, Meaver.

*Tremolite Serpentine.*—Eastern part of Goonhilly Downs, Kynance Downs, north of the Cove.

*Bastite Serpentine.*—South of Kynance Cove. The Balk, Kennack, Coverack.

*Chromite Serpentine.*—Half a mile south of Kynance Cove by cliff path, Kennack, Carrick Luz to Coverack.

*Tremolite Schist.*—Mullion Cove, Kynance, The Balk.

### **The Gabbro.**

The Lizard gabbro occurs as large intrusive bosses and as numerous dykes cutting the serpentine. The chief boss forms the area known as Crousa Downs, which is still to some extent strewn with weathered blocks of the gabbro, these are however gradually being broken up for road metal. A tongue of this mass runs in a south-easterly



direction to Carrick Luz. There is a smaller boss between Cadgwith and Landewednack.

The Crousa Downs gabbro is a coarse-grained purplish rock composed of felspar diallage and olivine, with some hypersthene and iron oxides. Under the microscope the felspars (labradorite) are often penetrated by acicular prisms of uralite which also fringe the pyroxene. The rock is not well exposed inland, but fresh material may be obtained by breaking one of the blocks to be found on Crousa Downs, or on the foreshore and in Perprean Cove. At Coverack, just below the Post Office, troctolite is to be seen passing into the gabbro of which it was apparently an early differentiation product. The contact of the troctolite with the serpentine is however sharply defined.

Most of the gabbro dykes consist of Flaser gabbro or gabbro pegmatite. They are coarsely crystalline rocks, often composed of crystals several inches in length, and they contain no olivine; the felspar is usually saussuritised or converted into a mass of white mica scales.

These dykes are very common round the coast, some of the best examples occurring at Parn Voose Cove, Kennack, and Carrick Luz, where the gabbro veins often show a most unusual aspect, being pale green fine-grained rocks in which the diallage has been entirely replaced by hornblende and the felspar almost completely saussuritised.

A further type is the Augen gabbro, which is a foliated rock with "eyes" of rounded diallage crystals. This occurs from Parn Voose to Carrick Luz and indicates that the rock was subjected to pressure after the crystallisation of its constituents while it was still plastic.

The only remaining type of gabbro is that of the gabbro schists which are in effect saussurite hornblende schists which sometimes form dykes and at others form part of the gabbro mass. The foliation of these rocks was due to stress and earth movements which took place during the consolidation and cooling of the rock.



### **The Black Dykes.**

Penetrating the serpentine and cutting the gabbro dykes there occur a vast number of dykes of basic character, some having the composition of dolerites, while others are epidiorites, i.e., they have had their pyroxene more or less completely changed to hornblende. These dykes are comparatively scarce on the west coast, but on the east they occur in such number that there are as many as ten in twenty yards. Their chief areas of occurrence are in or near the gabbro and round the Kennack gneiss. The majority strike in a north to north-west direction, but there is considerable variation.

In some instances they have been converted into schists by stress or pressure subsequent to their crystallisation, but as a rule they retain the characters of intrusive rocks better than the other igneous rocks of the Lizard; some of the dolerites in particular show well-marked ophitic character under the microscope. These dykes are worked for road metal in the Porthoustock district. When the dykes cut foliated gabbro it will be noticed that they cut across the foliation which does not affect them. This indicates that the dykes were intruded after the metamorphism of the gabbro.

In a few instances, notably at Poldurian and at Polbream Point the black dykes contain a certain amount of pink felspar and quartz. This is of special interest in connection with the Kennack gneiss which was intruded later.

Though black dykes can be found almost anywhere along the east coast of the Lizard and here and there along the west the following localities are worth notice:—Porthoustock Point, Cove west of Poldurian, Kennack, Kynance and Black Head.

### **The Kennack Gneiss.**

The last intrusion to be observed in the Lizard district was one of banded gneisses followed without break by



granite and granite gneiss. The banded gneisses have been called Kennack gneisses from the locality where they are best exposed and where they intrude into the serpentine in the form of veins, dykes, sills and irregular bosses.

They consist of intermixed acid and basic material, one forming a matrix for veins of the other, or including rounded patches of the other with indefinite boundaries. The whole rock is characterised by well-marked flow structure and foliation, one being parallel to the other. The basic material has the character of a hornblende schist or epidiorite of fine grain, while the acid material has the composition of a highly acid granite. Specimens can be obtained showing both types of material and all varieties of intermediate types due to absorption of one by the other. Where the gneiss penetrates the serpentine the margin of the former is usually converted into pseudophite, an alteration product of the felspar. This can be seen well a few yards west of the gate at Kennack, at the western end of Parn Voose Cove and at Gew Graze to the north of Kynance.

The Kennack gneiss can also be seen in the Devil's Frying Pan at Cadgwith and in Parn Voose Cove where it penetrates both gabbro and serpentine and the relations are extremely complex.

The origin of the Kennack gneisses has been the subject of much controversy. They were at one time considered to be older than the serpentine and black dykes. It is now generally accepted that they represent intrusions of two magmas of different composition which partly solidified before mixing had taken place. As we shall see later, similar mixed magma intrusions are to be found among the Land's End greenstone.

The granite gneiss covers a considerable area in the Lizard, forming a large part of Goonhilly Downs and occurring at Kennack, between Ruan and Cadgwith, and in the form of veins at Kynance. As it weathers much



faster than the serpentine it is inconspicuous inland, where it forms lower ground. One of the best inland localities is where the Lizard road crosses the southern end of the Goonhilly Downs where small pits show an outcrop of the granite which is cut by a vein of pegmatite containing tourmaline. So far as the writer knows this is the only recorded instance of the occurrence of tourmaline in the Lizard granite. At Kynance the granite occurs on the foreshore and in the top of the cliff to the north of the cove.

The next rocks of the Lizard in order of age are the Pliocene gravels of Crousa Downs which will be discussed in connection with the other Pliocene rock of Cornwall. From the granite gneiss intrusions to Pliocene times the geological history of the Lizard is a blank and no record of the acid intrusions which are so prominent to the north of the fault is to be found unless the pegmatite referred to can be considered as such.

There is still much work to be done in the elucidation of Lizard geology and much scope for careful field work systematically carried out.

### CHAPTER III.

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#### THE PALÆOZOIC SEDIMENTARY ROCKS.

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These rocks form practically the whole of the Cornish lowland north of the Lizard fault and were originally classified as the Greywacke series by De la Beche and are known to the Cornish miner under the comprehensive term "killas." Recent work has resulted in the rocks of the eastern part of the county being correlated as Devonian, while those to the west of a line running from Porthtowan to Veryan have been correlated in two ways owing to a difference of opinion as to the presence or absence of an unconformity at the base of the Grampound Grits. These western rocks have yielded very few fossils and those found so far have been restricted to one series, so that their age has been determined on structural and petrological characters.

Hill classified the western rocks into four series which he named the Mylor, Falmouth, Portscatho and Veryan series in ascending order.\* He considered them to be a continuous sequence, and to lie unconformably below the Grampound Grit, and as the Veryan series yields fossils of Middle Ordovician type the other series were considered to be older. Upfield Green and Sherborn† on the other hand considered that the Veryan series was the oldest and referred all the other series to the Lower Devonian and recognised no unconformity below the Grampound Grits. They considered the Mylor series to be altered Portscatho and the Portscatho series to be the western representative of the Grampound Grits. There are thus two divergent

\* Trans. R.G.S.C., Vol. XII. Geol. Mag. 1906. Mem. Geol. Survey Sheets 352 x 359.

† Geol. Mag., 1912, pp. 558-560; and 1915, pp. 70-73.



views as to the age of these rocks and the determination of the correct view is a piece of research that awaits a worker.

A glance at the map will show that the Mylor series as mapped surrounds the Carnmenellis granite outcrop and the view that it is the result of contact alteration of the Portscatho beds is widely held by Cornish geologists.

### The Veryan Series.

This series which is apparently the oldest of the Palæozoic system in Cornwall, outcrops across the north of the Lizard promontory from coast to coast immediately north of the Lizard fault. It is composed of slate, sandstones, cherts, thin limestone lenticles with pillow lavas and volcanic ash, and fossils have been found which enable us to correlate the beds as being of Ordovician age. The same series outcrops in the Veryan district, whence the name is derived, but there the relationship of the beds is much less clear and there is room for field work to settle the matter. The fossils which have been found include several species of *Orthis*, *Calymene*, *Favosites*, *Phragmoceras*, and crinoid ossicles; the cherts also contain radiolaria.

The most interesting localities for the study of these beds are as follows:—

Mullion Island, which can be reached by boat from Mullion Cove in calm weather, where the top of the island is formed of spilitic pillow lavas underlain by radiolarian cherts. These pillow lavas can be traced across the mainland to the east, but the outcrops are for the most part badly weathered and difficult of determination; one of the best localities is at Skyburriowe Mill, another is at Gallentreath near Porthallow. In these spilites the original structure is excellently preserved, which is quite the reverse in the case of the ordinary Cornish greenstones: they are often highly vesicular and sometimes variolitic. Near Roskruge porphyritic types of spilite occur.



There are also outcrops of dolerite at Cury and Tregidden, while the road-cutting south of Manacchan shows a brecciated granophyre in the Veryan slates, pebbles of which have been found in the Devonian conglomerate.

Another unusual rock in the Veryan area of the Lizard is the hornblende gneiss of the Gillan Creek area near Manacchan. This is intrusive in the Veryan beds and is less completely crystallised than the hornblende gneiss of the Lizard. It is as a rule highly brecciated and was probably intruded into the Veryan series in pre-Devonian times and brecciated subsequent to consolidation. Round this hornblende schist the clay slate is converted into mica schist or phyllite for a considerable distance.

The Veryan series extends on the east coast from Nare Head to Porthallow, yielding many excellent exposures. Just south of Penare on the coast, the outcrops of a band of quartzite forms a conspicuous feature: it dips south-west and is highly brecciated and cemented by secondary silica. The strike is apparently across that of the slates and is again found in the line of quartzite lenticles running from Treworgie Mill to Tregonnell Mill. This probably represents an early strike which preceded the Carboniferous movement, the hard quartzite resisting the movement and breaking into lenticles which retained the original line of strike.

Further south the beds are chiefly phyllite with a rough augen structure, in which are included lenticles of quartzite and chert: then follow alternating sandstones and slates which extend to Nelly's Cove, the sandstones being highly calcareous, while at Nelly's Cove there is a great development of chert bands and an outcrop of limestone on the beach. From Nelly's Cove to Porthallow Cove there is fine pillow lava with soda felsite, both much shattered, then phyllite with chert seams followed by sandy beds which are separated by a fault with well-marked breccia, to the south of which are the Lizard mica schists.



On the west coast the Veryan series extends from Gunwalloe Church Cove to Polurrian Cove and consists of sandy and argillaceous beds with occasional calcareous bands. They are much disturbed and are cut off from the Lizard rocks at Polurrian Cove by a fault having south-east.

In the Veryan district this series outcrops in a line running from Veryan to Gorran Haven, some of the best exposures being at Carne where the quartzite is well exposed in quarries; and at Kiberick Cove where a belt of crush breccia shows lenticles of limestone and quartzite in slate, together with large masses of gabbro and serpentine which closely resemble the Lizard types of those rocks and seem to have been torn up and carried along the overthrust which is seen in the cove as a series of crush-breccia belts separating Devonian rocks from those of Ordovician age. Pebbles of gabbro of a somewhat different type are found to the west of Nare Head.

Between Porthluney Cove and Hemmick Beach the Veryan beds are again exposed striking north-east. Here they include beds and lenticles of quartzite and of felsitic volcanic ash.

They appear again in the coast section between Gorran Haven and Great Perhaver Beach with a vesicular basalt in the middle of the outcrops; the slates of this area contain many thin beds of radiolarian chert.

The geology of this eastern area of Veryan beds is by no means thoroughly worked out and much careful field work is needed to elucidate the structure.

Visitors to the district must beware of the dangerous character of the coast. Long reefs stretch out nearly to low water mark and the foreshore should be explored during spring tides, starting with the falling tide to give time for the return journey to be made before the tide cuts one off.



## COUNTRY TO THE WEST OF THE PORTHTOWAN-VERYAN LINE.

This series of sedimentary rocks consists of slate, phyllites and grits with sills of basic igneous rocks. Coastal exposures at several points show the sediments to have been deposited in shallow water, as the grit bands often thin out in the slate beds and the alteration from slate to grit is frequent and irregular, indicating variation in conditions of deposition. This may be seen well in Hayle Cliffs and the Camborne North Cliffs, while the way in which the beds have been folded and faulted is especially well seen in Godrevy Cliffs.

Hill\* divided these rocks into three series, the Portscatho, Falmouth and Mylor series, the last occurring round the granite outcrops of Carnmenellis, Carn Marth and Carn Brea, and being in consequence metamorphosed for a considerable distance from the granite margins as well as much fissured and impregnated by mineral solutions. The general characters of each series as given by Hill are as follows:—

*Mylor Series.*—Blue argillaceous and fine sandy beds with a striped and ribbon-like appearance due to fine interlaminae of siliceous and argillaceous material. In some areas the laminae are argillaceous only but of varying composition and colour.

*Falmouth Series.*—Alterations of argillaceous and fine sandy material varying in colour from green to buff. On decomposition the beds become extremely friable, unctuous to the touch and weather to a deep buff colour.

*Portscatho Series.*—Blue and grey slates alternating with harder beds varying from sandy slate to grit. The sandy beds contain much clastic mica.

As the above descriptions show, there is but little difference between the series, and it is very probable that the characters of the Mylor series are due in great part to alteration produced by the granite intrusions.

\* Geol. Survey Memoir Sheet 352.



To the east of a line running from Porthtowan to Veryan there are beds of undoubted Devonian age which yield many fossils. These beds extend to the Devon border with the exception of a small area in the north-east of the county which is occupied by Culm Measure rocks.

The Devonian beds have been classified as follows :—

Upper Devonian.

Middle Devonian.—Plymouth limestone, and slates.

Lower Devonian.—Staddon grits, Meadfoot beds,  
Dartmouth slates, Grampound grits. Manaccan series.

### **The Lower Devonian.**

These consist of conglomerates, sandstones and clay slates, generally more or less calcareous, arranged in a great anticlinal fold with an east and west axis: thus in passing from south to north we pass from sandy strata on the south, including the Grampound grits, to calcareous slate and grit with thin limestones, the Meadfoot, then over the Dartmouth slate on to the Meadfoot beds again, and in the north on to sandy beds including the Staddon grit. These are followed to the north by the Middle Devonian slates and then by the Upper Devonian slates with thin beds of limestone.

The whole series is greatly disturbed and repeated by overthrusts, and the recognition of definite beds is a matter of great difficulty, especially as the lower series contain very few fossils.

The best way to study these rocks is to follow the coast section from Porthtowan to Padstow, but here the western part of the section is complicated by the occurrence of mineral lodes which cause the true characters of the beds to be marked by alteration products.

The Grampound grits may be studied in Ladock quarry where they are exposed as a coarse gritty felspathic sandstone containing angular fragments of slate sometimes



so large and numerous as to form a true breccia. They have yielded one fossil, a *Spirifer*, but as a rule are devoid of fossils. They extend in a westerly direction from Pentewan through Grampound to St. Agnes. On the north the Grampound grits are represented by the Staddon grits, which strike almost east and west across the county from Mount Edgcumbe to Mawgan. They consist of sandy silts containing bands of felspathic grit and bands of chloritic grit of greywacke type. These can be studied at Denzell quarry near Mawgan. Between these two outcrops lie the Meadfoot and Dartmouth beds, the latter occupying a triangular area inland from Watergate Bay and extending south of Lostwithiel from St. Winnow to Talland, with faulted patches as far east as Raine Head.

The Meadfoot beds consist essentially of dark grey slates with beds of sandstone and grit which become calcareous and also fossiliferous in their upper part. These fossiliferous beds can be well studied round Polruan and between Newquay and St. Columb Porth on the north coast. The Dartmouth beds are variegated slates showing purple, green and grey shades, which are well exposed in Watergate Bay, where they yield fossil fishes, as is also the case with the south-eastern outcrop.

The Middle Devonian beds consist of slates below with limestone or slates and volcanic rocks above. The Middle Devonian limestone is practically confined to Devon except for a small patch at Cremyll, the continuation of the Stonehouse outcrop, but the slates are found over a large area with numerous basic igneous rocks and beds of volcanic ash. The Upper Devonian beds are exposed in the coast north of Padstow where they consist of slates with occasional thin limestones, beds of volcanic ash, spilitic lavas, etc. It is chiefly in the extreme east and north-east of the county that the Culm measures outcrop, consisting of shales, grits, cherts and lenticular limestones with pillow lavas. These beds are frequently fossiliferous and contain



plant remains. There are also outliers of Culm measures at St. Dominic and near Dunterton.

Those interested in the fossils of Cornwall will find detailed lists in the papers by J. H. Collins in the *Transactions of the Royal Geological Society of Cornwall*, Vol XI., part vii, and Vol XII, part vi, which can be obtained from the Museum of the Society, Penzance.

The economic uses of the sedimentaries are numerous and varied. The Devonian slates of the Delabole district are worked for roofing slate and yield material of excellent quality. The hardened altered slates make good road metal: some of the western slates have been worked for hone stone, while the slates from districts unaffected by mineralisation form durable building stone easy to dress. The grits are quarried for road metal and many of them would form good grinding stones. The altered slate at Treamble (see Chap. VIII. p. 64) gives an earth very similar to Fuller's Earth in its properties, and is being worked on a large scale. Some of the slates in the Devoran district yield oil on distillation, but their structure is too complex to make profitable exploitation possible.

Recent workers on the Cornish Palæozoic sedimentary rocks of West Cornwall have put forward new views as to their relative ages, but the work done has been of a local character. The formation of a British Association Committee to investigate these rocks will, it is hoped, bring new light to bear on this subject.

## CHAPTER IV.

### THE BASIC IGNEOUS ROCKS.

The basic igneous rocks of Cornwall, excluding those of the Lizard, include both intrusive rocks and contemporaneous volcanic flows. The former are of Devonian or earlier age, that is, they were intruded before the intrusion of the granite and have shared in the folding to which the sedimentary rocks have been subjected. These basic rocks can be classified as follows:—

|                 |   |                                                               |                          |
|-----------------|---|---------------------------------------------------------------|--------------------------|
| Contemporaneous | { | Schalstein tuffs.<br>Spilites and pillow lavas.               |                          |
| Intrusive       | { | Lamprophyre<br>Epidiorite, proterobase<br>dolerite<br>Picrite | The<br>Green-<br>stones. |

The picrites occur at Menheniot, Polyphant, near Launceston, and Duporth near Charleston. At the first locality the rock is quarried at the railway station being used by the railway company for ballast and road metal. It is a serpentinised picrite much sheared and faulted showing excellent examples of slickensides. The Polyphant rock is of similar type, but the exposure at Duporth is of an almost completely serpentinised rock which was originally apparently very rich in olivine.

The name Greenstone includes the numerous sills and dykes of basic igneous rocks which are so numerous in the west of the county. They were described by Allport and Phillips\* and have considerable petrological range,

\* Q.J.G.S., Vols. XXXII and XXXIV.



though most are dolerites in which the augite has been more or less completely replaced by hornblende. There are, however, some types which were apparently andesites, but the effects of dynamic metamorphism have in most cases so altered the structure and composition of the rock that the determination of its original character is a matter of great difficulty. The junction of the greenstone with the slate can be studied at many coastal sections as well as inland exposures. In each locality it is evident that the greenstone has altered the slate in contact with it, often resulting in the formation of a fine-grained adinole such as may be seen at Gurnard's Head, Porthmeor Cove, St. Ives Island, Penlee quarry, etc. The relation of the greenstone to the granite can also be observed at Tater Du, west of Lamorna Cove, Pendour Cove, north of Gurnard's Head, where the greenstone is cut by veins of granite. In Pendour Cove there is an especially interesting rock\* which shows a mixture of acid and basic material, giving the rock a pink and black streaked appearance. This rock is cut by granite veins and quartz tourmaline veins, so is of earlier date than the granite, and seems to have originated from a magma of mixed composition. It may perhaps represent the last stages of the basic intrusions when the magma reservoir was becoming acid.

The greenstones have shared in the folding which the surrounding slates have undergone and their outcrops are in consequence repeated by folding, so that one often meets with rapid alternations of slate and greenstone such as are to be seen in the coastal section west of St. Ives and in Botallack cliffs. The larger bodies of greenstone outcrop over long distances as a result of folding, as is the case between Penzance and Redruth, where greenstone outcrops follow one another in line in a north-easterly direction for almost the whole distance. In sinking the new Roskear

\* Report Royal Corn. Polytechnic. Trans. R.G.S.C., Vol. XV. Part VI., 1925.



shaft greenstone was repeatedly encountered in the shaft, the result of isoclinal folding.

In many cases the greenstones have been subjected to such pressure that the rock is full of small shear planes and the minerals have been drawn out into feathery aggregates, a character which is especially well shown in the quarry half a mile on the Falmouth side of Ponsanooth. Occasionally in localities well away from the granite outcrops the greenstones show well-marked ophitic texture, this being the case with several of the outcrops on the south coast, especially the sills which outcrop on the fore-shore at Porthleven.

Another type common at Porthleven is a highly porphyritic rock with large phenocrysts of white felspar which seems to penetrate the ophitic types of greenstone.

In composition the greenstones are very varied, the essential minerals being felspar, most of which shows lamellar twinning, hornblende and iron ore, ilmenite or titaniferous magnetite; accessory minerals include epidote, biotite, pyrrhotine and apatite, while the chief secondary minerals are chlorite, sphene, leucoxene, calcite, quartz and limonite. Augite occurs probably as the result of thermal alteration and associated with it are axinite, tourmaline, and garnet.

The greenstone quarry at Carrick Du, St. Ives, is noted for the fine specimens of axinite, zoisite, calcite, actinolite, etc., which are to be found there when the quarry is in operation. Another unusual type of altered greenstone is to be seen at Trevalour quarry, Penzance, which is bleached and spotted, the spots being composed of hornblende, axinite and pyrrhotine.

The greenstones occur throughout the Devonian rocks to the east where they are often less altered and show their original characters more clearly. In the Padstow area a number of sills of proterobase occur, their essential minerals being soda-felspar, augite, biotite and brown horn-



blende with serpentine enclosed in the ferromagnesian minerals; another group of outcrops in the St. Minver area show rocks of different character with occasional ophitic structure: they are closely allied to the essexites. Quartz diabase occurs at St. Mewan and Black Head, while the intrusive rocks to the north of St. Breward are all epidiorites.

The various types of intrusive basic rock may be classified as follows:—

1. Picrite ... ... Menheniot, Duporth, Polyphant.
2. Epidiorite ... ... West Cornwall.
3. Ophitic diabase ... Porthleven, St. Austell.
4. Proterobase ... Rock, Cataclase.
5. Quartz diabase ... Black Head, St. Mewan.
6. Diabase porphyrites Porthleven.

*Dolerite?  
Black  
+ Augite.*

It should be noted that these basic rocks are often spoken of as "blue elvans" or simply "elvans" by the Cornish miner and quarryman, which is likely to mislead the student unaware of the wide local application of the term "elvan"; the author has even heard it applied to the Ladock grit.

The basic volcanic rocks of Devonian age in Cornwall are either pillow lavas of spilitic character or volcanic ashes of schalstein type and are restricted to the Middle and Upper Devonian. The spilites are fine-grained vesicular rocks without conspicuous phenocrysts. They are composed of laths of plagioclase felspar showing flow structure. The augite is practically all altered and was not present in large crystals: it is represented by chlorite, calcite and quartz. Ilmenite changing to leucoxene is common but there is but little apatite. There is no indication of the rock having ever contained olivine. The spilitic at Pentire Point is much more coarsely crystalline than the average and shows the typical pillow structure which is to be seen in nearly all the spilitic rocks.

The schalsteins are in many cases true volcanic tuffs, but may in some cases be brecciated lavas. They show intrusive shearing with satin-like lustre on the cleavage faces and are composed of calcite, chlorite, secondary quartz, iron oxide and a certain amount of felspar. The rock often approximates to a calc-chlorite schist. While the pillow lavas are often to be seen in fresh condition in cliff exposures the schalsteins are generally so decomposed as to give very poor exposures. They seldom outcrop inland and have been repeated by folding so that their outcrops have a much greater extension than is warranted by their thickness.

Many of the basic igneous rocks form excellent road metal and are worked for that purpose in numerous quarries, one of the largest and most important being at Newlyn whence the stone is shipped in large quantities. As noted above, the picrite is worked at Menheniot and also at Polyphant and may be found on almost any railway track in the county. The finer-grained types form the best road metal. Cornwall should possess ideal roads with the plentiful supply of first-class road metal available.



## CHAPTER V.

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### THE CORNISH GRANITES.

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The granites of Cornwall occur as a series of separated outcrops running in an east-north-east direction from the Scilly Isles to Dartmoor in the neighbouring county of Devon. These outcrops form rounded hills rising out of the Palæozoic rocks into which tongues and veins of the granite extend. The holocrystalline character of the granite shows that it cooled very slowly, the result of the thick slaty cover which it once possessed, while it also consolidated under high pressure, as is shown by the fact that several of its component minerals, such as tourmaline, topaz, etc., can only be formed under conditions of high pressure. The temperature of the magma from which the granite consolidated was probably only moderate, about  $500^{\circ}$ - $600^{\circ}$  C, having been suggested and fluidity being maintained by the presence of fluxes of which more will be said later. The presence of granite at the surface now is therefore the result of long-continued denudation which resulted in the removal of much of the slaty cover and in some cases of a considerable thickness of the granite. One result of the denudation of the granite is the occurrence of residual boulders on the hill top which, with their artificial appearance, due to the system of jointing, have no doubt helped to add to the belief in Cornish giants of times past.

All the granite outcrops possess a common system of jointing consisting of horizontal joints or "floors" and two directions of vertical joints, the toughway and cleavingway joints. The "floors" are not strictly horizontal, but actually concentric to the original granite surface: thus



they incline downhill along the edge of the granite outcrop. The interval between the floors varies in amount, with the depth below the granite surface: near the surface they may be only a foot or so apart, but in depth the interval increases till it may reach as much as 60 feet. The cleavingway joints run in a north-north-west direction and the rock splits readily in a direction parallel to these joints owing to the lie of the felspar crystals. The toughway joints run east-north-east and it is along these that veins of fine-grained granite and aplite occur, while the elvan dykes and the mineral lodes have a similar direction. These toughway joints often fault the "floors." There is a close connection between the joint directions and the grain of the granite: the micas and felspars seem to lie with their flat sides horizontal, i.e., parallel to the "floors," while the long axes of the felspars lie parallel to the cleavingway joints, this explains why the granite usually splits most easily parallel to the floors and secondly parallel to the cleavingway joints, while it is almost impossible to split it evenly parallel to the toughway joints. This mural jointing in the granite is the cause of the castellated appearance so well seen in the cliffs of the Land's End promontory; it also enables large blocks to be easily obtained in quarries situated near the heart of the granite mass, while as weathering acts most readily along the joint planes we get as a result wall-like tors and occasionally logan rocks.

The contact of the granite and slate is by no means regular. As a general rule the granite slopes beneath the slate at a moderate angle, while where mining development has been extensive, as in the Camborne-Redruth district, this slope is seen to be an undulating surface as one passes away from the outcrop, so that at a considerable distance from the outcrop the igneous rock is at no great depth. The regularity of the granite surface is broken by veins and apophyses which penetrate the surrounding slate for a considerable distance. At Porthmeor Cove, for example, the granite veins are seen 250 feet above the main body,



and in the shafts recently sunk at Tolgus and Roskear mines veins of granite were cut some 400 feet above the main mass.

The margin of the granite is usually of much finer grain than the central part of the outcrop, and this fine-grained character is particularly noticeable in the smaller bosses which, owing to their small size, were more effectively chilled by the surrounding slates. Thus, at St. Michael's Mount, St. Agnes, and Castle an Dinas, near St. Columb, the granite has the texture of a granite porphyry at surface but becomes more coarse in grain as it is followed downwards. The larger bosses were no doubt surrounded by such a thick belt of heated slate that the chilling was but slight.

It has generally been maintained by those with the most intimate knowledge of Cornish geology that the various granite outcrops are not separate individual intrusions, but minor bosses or "cupolas" on one huge ridge of granite extending from Dartmoor to the Scillies, which, while not necessarily the result of one intrusion, was derived from one magma reservoir. The underground connection between the outcrops has in some cases been proved to exist by underground workings. Thus, the Condurrow, Grenville, and Basset mines showed that the Carn Brea ridge is connected underground with the Carnmenellis mass as their shafts all passed from slate to granite at depth varying from 120-180 feet and a connection between Carn Marth and Carnmenellis outcrops has been shown in a similar way. There is also much evidence to show that the other outcrops are similarly connected, which is briefly as follows:—

All the outcrops have a common system of joints which have the same bearings in each outcrop.

The metamorphic aureole of one granite outcrop often extends towards the next. Thus the aureole of the Carnmenellis mass extends on the northern side to the coast



and in north-easterly and easterly directions to Perranporth and near Truro respectively. The occurrence of detached metamorphic areas between the aureoles of the outcrops such as those at Gwinear, Godrevy and Tremore Bridge,\* and the occurrence of granite at Bridge,† show that the granite is often at no great depth at points far from the outcrops. It has also been suggested by Mr. Coon‡ that the frequent occurrence of springs on the summits of the granite hills is evidence of continuity of drainage system (and thus continuity of the granite) between the higher and lower outcrops.

In composition also the various outcrops are remarkably similar, to such an extent that separate origins of the various outcrops seem impossible. While each outcrop has certain peculiarities which characterise it there is a strong general similarity, all being alkaline granites composed essentially of quartz, orthoclase, and both micas, with a subordinate amount of albite: apatite, pyrite, tourmaline and zircon are common constituents.

There are two contrasted types of granite, both of which are to be seen in most of the outcrops, the coarse-grained granite and the fine-grained granite. The Geological Survey refers to these as the older and younger granites respectively, but the author's experience is that instances of mutual penetration of the two types are so common that they seem to be of approximately the same age, their difference in texture being due to variation in composition of the magma, which is borne out by the practical absence of muscovite in the fine-grained type in which biotite is present in plenty.

There is no evidence of absorption of the country rock by the granite or so-called magmatic stoping; the contact between the two rocks is usually a sharply-defined line,

\* Trans. R.G.S.C., Vol. XV, part VIII, 1926.

† Trans. R.G.S.C., Vol. XV, part V, 1925.

‡ In a personal communication.



and the only approach to absorption is the occasional occurrence of *lit-par-lit* intrusion of the slate by the granite. Xenoliths of slate are often found in the marginal granite in the form of sharply defined angular fragments, often altered to mica schist from the outside towards the centre which consists of almost unaltered slate.

The varieties of altered granite are exceedingly numerous and will be discussed in Chapter VIII, but it should be noted that there is evidence of the continuation of crustal movement after the intrusion of the granite, as in some cases, especially in the Ponsanooth area, the granite shows incipient foliation.

The date of the granite intrusions has been approximately determined from a study of the rocks it has altered. In Cornwall it alters the Devonian rocks, while in Devon the Culm Measures are altered, thus the age of the granite can be shown to be post-Carboniferous, the intrusion forming the climax to the long series of earth movements which have raised the slaty rocks into the series of anticlines described in the last chapter.

The chief characteristics of the various granite outcrops are as follows :—

### **Scilly Islands Area.**

This area shows two types of granite, a predominant coarse-grained porphyritic type surrounding a central area of fine-grained non-porphyritic granite, the boundary between the two being indefinite, one type passing gradually into the other. The porphyritic type shows felspar phenocrysts of an inch or more in length which show a well-developed flow structure; there is little plagioclase and tourmaline is as a rule scanty, but occurs in veins and patches. The fine-grained type is similar in composition but contains more tourmaline. The coarse-grained granite is traversed by veins of fine-grained granite and by pegmatite veins and contains small oval patches







of more basic composition. There are also fissures filled with greisen and schorl rock which cut the granite and pegmatite veins.

### **Land's End Area.**

This area is composed essentially of a coarse-grained granite often highly porphyritic with areas of fine-grained granite at Castle an Dinas and Knill's Monument. The porphyritic type is notable for the large size of the orthoclase phenocrysts, which are often as much as six inches in length. It is also characterised by the presence of hexagonal prisms of pinite and much andalusite. It is penetrated by veins of fine-grained granite, aplite, greisen and schorl rock and areas of highly-tourmalised granite and of china clay rock occur. The fine-grained granite in both localities contains much topaz, and at Castle an Dinas pinite is a common constituent. It is notable that the area round Castle an Dinas occupied by the fine-grained granite is free from tors which are such a prominent feature on the coarse-grained type.

### **St. Michael's Mount.**

The southern half of the island is formed of granite which extends to the south below low water mark. On the island the rock has the texture of a granite porphyry with idiomorphic crystals of quartz and felspar, but becomes more normal in texture on passing south. It contains much topaz and is remarkable for the great development of greisen veins. Tourmaline is present in unusually small proportion.

### **Godolphin and Tregoning Area.**

This outcrop consists of granite of medium texture, but is more or less kaolinised over the whole area. It contains much gilbertite mica and some pinite and is traversed by veins of greisen and pegmatite.



**Carnmenellis and Carn Brea.**

This area is composed for the most part of coarse-grained granite which is often porphyritic, but not so coarsely porphyritic as the Land's End mass; it contains both mica, tourmaline and andalusite, but pinites and topaz are rare. It is cut by veins of aplite, pegmatite, schorl rock, and it shows many varieties of altered rock in the mineralised area. An area of kaolinised granite has been proved near Menherion. Fine-grained granite occurs near Praze and at Crowan Beacon, and the coarse- and fine-grained types are here seen to penetrate each other.

**Carn Marth.**

This hill is composed of a coarse-grained granite similar to that of Carnmenellis with exposures of fine-grained granite at Harvey's quarry and on the hill above. There are numerous veins of aplite and pegmatite as well as areas of tourmaline granite and a kaolinised area near St. Day.

**St. Austell or Hensbarrow Granite.**

This granite is coarse-grained and highly porphyritic with felspar phenocrysts up to five inches in length. It contains andalusite and cordierite as common constituents, but is chiefly notable for the great extent of kaolinisation, especially in the western part of the outcrop. The granite is penetrated by numerous veins of aplite and pegmatite and also by bands of schorl rock and greisen.

**Bodmin Moor Granite.**

The granite of this area is of medium grain with no strongly marked porphyritic texture such as we meet in the Land's End district; in general characters it is similar to the Carnmenellis mass but shows a tendency to a finer texture towards the margin. It almost invariably contains original tourmaline and often shows flow structure. There



are but few quarries as the problem of transport has to be overcome and renders the working of quarries in this district unduly costly. There are several large masses of fine-grained granite in the normal coarse-grained rock and these are considered to intrude the main mass. They occur at St. Breward, Bolventor, and Dozmary Pool; the first has a dyke-like prolongation which is cut by the De Lank river.

The granite is used locally as a building stone at all points near the outcrops and is quarried on a large scale for export in areas free from mineralisation, the most important being the area west of Penryn. Unfortunately it has to compete with the cheaper foreign granites and its superiority to most of the foreign stone is not properly appreciated. Many of the granites make exceedingly handsome stones when polished and if free from mineralisation their life as a building stone is practically unlimited, as can be seen by an inspection of the old Cornish churches.

The fine-grained granites form excellent setts and a very fine road metal, but the coarse-grained type crushes too easily to be good road-making material.

The chief quarrying districts are Newmill and Sheffield near Penzance, Constantine and Long Downs near Penryn, Gready quarry in Luxulyan Valley, Delank quarry north of Bodmin, Cheesewring quarry near Liskeard.

#### MECHANICAL ANALYSIS OF GRANITES.

| Locality.            | Quartz and |   | Biotite. | Muscovite. <sup>1</sup> | Tourmaline. |
|----------------------|------------|---|----------|-------------------------|-------------|
|                      | Felspar.   |   |          |                         |             |
| 1. Long Downs ...    | 54.8       | % | 6.9      | %                       | 0.6         |
| 2. New Mill ...      | 55.1       | % | 7.5      | %                       | nil         |
| 3. Sheffield Qy. ... | 58.2       | % | 6.2      | %                       | 2.3         |
| 4. Lamorna ...       | 60.3       | % | 8.1      | %                       | nil         |
| 5. Geevor ...        | 61.4       | % | 1.5      | %                       | 6.1         |
| 6. Polhigey Mine ... | 59.3       | % | 2.1      | %                       | 6.9         |
| 7. Condurrow ...     | 60.3       | % | nil      | %                       | 7.4         |
| 8. Parc-an-chy ...   | 59.4       | % | nil      | %                       | 8.1         |
|                      |            |   |          |                         | Fluor 5.8   |

1—4 Districts void of mineralization.

5—8 Mineralized areas.

1 Includes lithia and fluor-bearing micas.

## CHAPTER VI.

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### THE MINOR INTRUSIVES.

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The intrusion of the granite was followed by a series of intrusions of acid magma, most of which were slightly more acid than the granite itself. The chief types of rock formed by these intrusions are, in order of age :—

1st Pegmatites and Aplites.

2nd Quartz porphyries ("Elvans").

Also Minettes (Mica Traps) the age of which is doubtful.

The pegmatites are very coarsely crystalline rocks which run in veins of variable direction and width, both through the granite and the surrounding slates. They contain such minerals as tourmaline, fluorite, fluorapatite, lithia and fluor bearing micas, pinite and occasionally andalusite, with such metallic minerals as cassiterite, wolframite, arsenopyrite, and in a few instances torbernite.

Frequently the pegmatite veins consist of alternating bands of pegmatite and aplite or of a pegmatite centre with a selvage of aplite : also in several instances pegmatite veins have been observed to pass laterally into aplite and this in turn to vein quartz, reminding us forcibly of alaskite\* in its relations.

It is well established that the pegmatites were intruded at a low temperature as the contact alteration along their margins is of the slightest character often not extending more than two inches from the walls of the vein. Also,

\* Spurr. Ore Magmas, Vol. 1.



xenoliths of slate in the pegmatite show only slight marginal alteration, the centre of the xenolith retaining its typical slaty characters.

The pegmatites occur in greatest numbers around the edges of the granite masses, but they also occur in the central parts of the outcrops and the Dolcoath Williams shaft cut a pegmatite containing cassiterite, garnet and andalusite at a depth of over 3,000 feet in the granite.

One of the best exposures of pegmatite veins is at Megilgar rocks a mile and a half west of Porthleven, where veins of pegmatite run almost horizontally through the slate for a distance of over a hundred yards from the granite. The veins show alternate layers of aplite and pegmatite and include xenoliths of slate often scarcely altered, which indicates the low temperature of the magma at the time of intrusion. This is also shown by the slight amount of contact metamorphism produced in the slate by the pegmatite. The veins contain tourmaline, lithia mica and mispickel.

Another good exposure is at Trelavour Downs, above St. Dennis, where a pegmatite vein shows segregation banding with a margin of dark brown mica and pink felspar passing into fine and then coarsely crystallised mica with a centre of coarse felspar, mica and quartz. The mica is said to contain 1.5 per cent. lithia ( $\text{Li}_2\text{O}$ )<sup>†</sup> At Tresayes Downs above Roche another pegmatite vein occurs which shows exceptionally large felspar crystals with quartz, tourmaline, pale mica and a little fluorspar.

The pegmatites have been worked for their felspar in the past but at the present time the works are in a state of suspension.

The aplites are fine-grained rocks composed of quartz and felspar with muscovite, tourmaline and topaz as subordinate components. They occur in great numbers as

<sup>†</sup> Geol. Survey Memoir Sheet 347, 1909, p. 63.



narrow veins in the granite and occasionally penetrate the slates. As noted above, they occur in alternate bands with pegmatite, their fine-grained texture being apparently due to the lack of fluxes which were plentiful in the magma which formed the pegmatites. The margins of the aplite veins often contain large crystals of felspar derived from the surrounding granite, which suggests that the granite was not thoroughly solid at the time of the arrival of the aplite magma. As noted before, aplite veins have been observed to pass gradually into quartz veins.

The Cornish aplites are not of sufficient size to be of economic use, but at Meldon, near Okehampton in Devon, a dyke of aplite is quarried for glass-making material.

### **The Quartz Porphyries or Elvans.**

These dykes occur in great numbers both in the granite and the slate. The Cornish name "Elvan" is often used to indicate these rocks, but it must be used with great caution, as the Cornish miner and quarryman applies it to any hard rock not typical granite. Thus fine-grained granites, aplites, and even grits have been described to the author as elvans, while "blue elvan" signifies a greenstone.

The quartz porphyry dykes of Cornwall include granite porphyries, quartz and quartz felspar porphyries, microgranite and granophyres and vary greatly in colour and texture. When exposed at surface they are usually buff or grey in colour, but when cut underground they often have a greenish-grey colour with almost the lustre of a phonolite from which they can, however, be readily distinguished by the presence of quartz crystals.

The great majority of the dykes strike in an east-north-east direction, that is, in the same direction as the cleavingway joints of the granite. Many are of great length, some having been traced for over seven miles, while others occur in a series of separate outcrops in



line which suggests that the dyke has an uneven upper surface. In width they vary from a few feet up to 40 or 50 feet and usually dip at an angle of  $30^{\circ}$  or more with the horizontal, many being practically vertical. The margins of the dykes are as a rule fairly regular in the slate but more irregular when in the granite, and generally the marginal portions of the dykes show the characters of chilled margins often with flow structure.

The same dyke may vary in character as it is followed along the strike; for instance, the dyke in Newham quarry (on the west side of the river just below Truro) is a fine-grained felsitic rock with a few scattered phenocrysts of quartz, but on following it westwards to Baldhu it appears as a porphyritic rock with crystals of quartz and felspar, and further west near Chacewater it is still more crystalline. The dykes frequently contain xenoliths of the country rock (both slate and granite) which show little sign of alteration, though the granite xenoliths occasionally show signs of partial melting. These xenoliths may occur at unexpected spots, for instance, a large one was observed in the quartz porphyry dyke at Bridge,\* near Illogan, some two miles distant from the granite outcrop.

The jointing of the elvans is usually irregular though one now and then sees a rough prismatic jointing, the prisms running at right angles to the walls of the dyke. This character has been noted at Brea quarry near Camborne, and in the quarry at Tremore Bridge near Lanivet.

A few of the elvans contain graphite as films on the joint planes or as included blebs which seems to have been derived from the surrounding slate; others are brecciated and cemented by cassiterite or are penetrated by numerous veinlets carrying cassiterite, chalcopyrite, pyrite or mispickel, so that in such cases as Wheal Busy and Parbola mines the dyke forms the main ore body.

\* Trans. R.G.S.C., Vol. XV, part v, 1925.



In composition the quartz porphyries consist of a fine-grained ground mass composed of microcrystalline quartz, felspar and muscovite, enclosing phenocrysts of quartz (usually in bipyramid crystals or irregular blebs), orthoclase and biotite which is usually largely chloritised. Tourmaline, pinite and fluorspar are common constituents, while the accessories include apatite, zircon, pyrite and pyrrhotite. The proportion of ground mass varies from very little in the granite porphyries, to almost the whole of the rock in the microgranite, while the granophyres are largely composed of a micrographic intergrowth of quartz and felspar. No pitchstone types are known to occur in Cornwall. It will be described later how the quartz porphyries have shared in the various pneumatolytic changes which have affected the granite, giving rise to tourmalinised, greisenised and kaolinised types of the rock.

### **The Mica Traps or Lamprophyres.**

Well away from the granite margin and outside the metamorphic aureole the slates are here and there penetrated by sills of basic type which show the character of mica traps. These rocks weather readily and in consequence are as a rule only to be seen in coastal sections and river banks: there are probably many more than those whose occurrence has been determined. The localities where they are best exposed are the banks of the River Fal, Helford River, and near Newquay.

They are essentially composed of felspar and biotite while the chief accessories are apatite, quartz, and calcite; augite is rare. As the felspars are usually much decomposed, their true nature is difficult to determine and it is possible that both minettes and kersantites are included in the group. The micas are often bent and sometimes bleached to a white colour.



Though usually occurring as sills, they occasionally show a dyke character and seem to have been intruded after the cleavage but before the folding of the slates.

The quartz which occurs in these is usually present as inclusions, sometimes of considerable size, which have probably been picked up from the quartz veins in the enclosing slates. No section is now known where the mica trap is in contact with another igneous rock, but Collins\* states that he observed a mica trap cut by a quartz porphyry at Treliske, which would show that these rocks are of greater age than the elvans. They weather very readily and their outcrops are usually soft and decomposed, often with a heap of rusty sand at the base.

The economic uses of the pegmatite and aplite have been mentioned above, and it only remains to deal with those of the quartz porphyries and mica traps. The former have in the past been largely used as building stone and often form very handsome stones of great durability. Many are exceedingly handsome when polished and well worth more attention. The finer-grained and fresh types form very fair road metal and are largely used for this purpose. The elvans also usually carry water and a well sunk on an elvan dyke will usually yield good water if the rock is not mineralised.

Penzance draws its water supply from an elvan dyke.

The only use to which the mica traps have been put is that their decomposed waste is used as a manurial dressing, probably on account of its potash content.

\* Jour. R.I.C., Vol. VIII, pp. 197 and 202,

## CHAPTER VII.

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### THE CONTACT ALTERATION PRODUCED BY THE GRANITE.

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When the great intrusion of magma which solidified to form the granite took place, the surrounding rocks were subjected to two types of alteration, namely, that resulting mainly from the heat given off by the granite, and that resulting from the action of vapours and solutions given off by the consolidating magma.

The first type of alteration is termed contact or thermal metamorphism, and is confined to the rocks surrounding the granite; the second type is termed pneumatolytic and hydrothermal action and affects the granite itself as well as the surrounding rocks: it will be discussed in the next chapter.

The contact alteration results in a zone or aureole of altered rocks which surrounds each granite boss. This belt varies in width at surface with the slope of the granite below the overlying rocks; the more gentle the slope the wider will be the aureole.\* At the same time the structure of the slaty rocks has affected the width of the metamorphic aureole, as well as the variation in their composition.

During the last few years three new shafts have been sunk in the Camborne-Redruth area to the north of the Carn Brea granite, and a careful study of the rocks they have passed through has added much to our knowledge of the contact metamorphism of the area.\*

\* Geology of East Pool and Agar Shaft, Mining Mag., December 1922. Geology of Roskear Shaft, Mining Mag., June 1925, and March 1919.



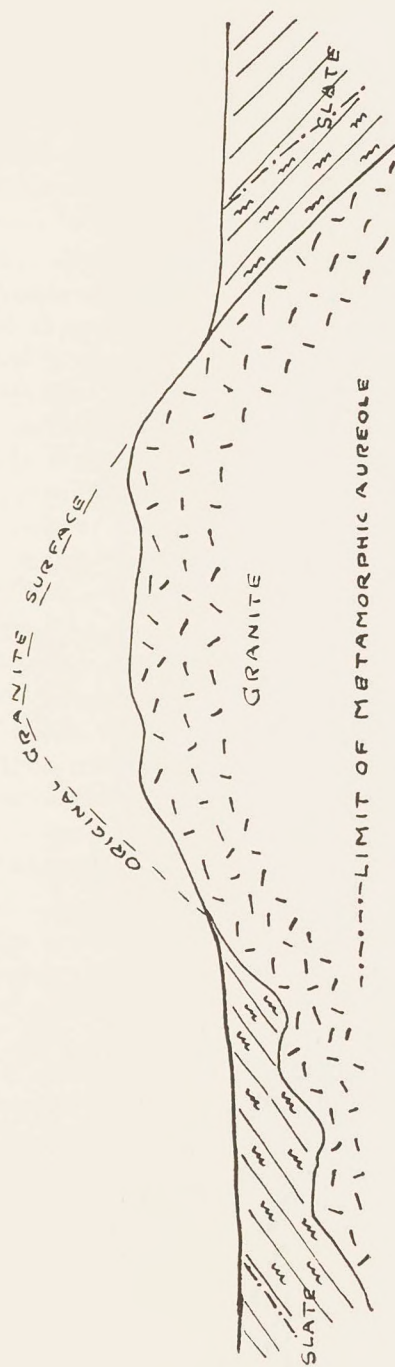


FIG. 3 SHOWS RELATION OF METAMORPHIC AUREOLE  
TO GRANITE SURFACE.

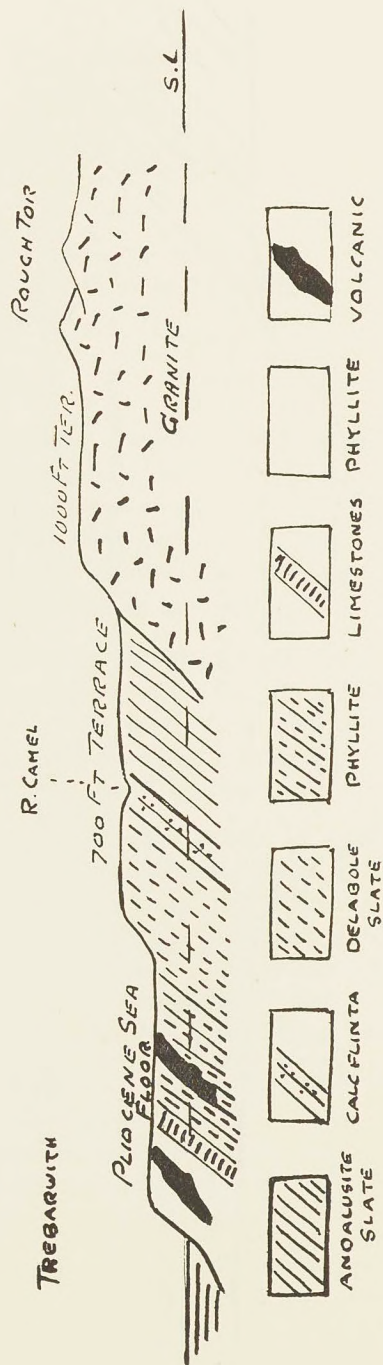


FIG. 4. SECTION IN CAMEL FORD AREA.



They show, for instance, that the vertical thickness of the aureole is at least 2,000 feet, as Tolgus Shaft starts in spotted slate at surface and has not cut the granite at a depth of 2,000 feet.

They also show that the general character of the contact metamorphism, so far as the slate is concerned, is a series of alteration zones showing different types of altered rock, which succeed one another in depth as the granite is approached. The thickness of these zones is not by any means uniform, but the sequence seems to be the same in widely separated districts. At the same time it must be borne in mind that the character of the altered rock, especially near the granite, is often obscured by pneumatolytic change. The general arrangement of these zones is as follows:—

Slate free from contact alteration.

Spotted or knotted slate.

Andalusite, chiastolite or ottrelite slate.

Phyllite with pyrite or pyrrhotite.

Mica schist with more biotite than muscovite, often tourmalinised, penetrated in lower levels by veins of aplite, pegmatite and granite.

Granite bed rock.

The spotting, which is the only indication of contact alteration in the outermost zone of the aureole, persists to a considerable depth, but is less conspicuous in the darker rocks of greater depth. Andalusite has been found in the altered slate 600 feet above the granite and is the usual form of aluminium silicate, chiastolite being of rare occurrence in Cornwall. Garnet is occasionally found in the slates near the granite, while if there are greenstones in the vicinity actinolite is a common alteration mineral. These types of altered slate can be seen in the waste heaps at East Pool, Tolgus and Roskear shafts.

The rocks of the metamorphic aureole include not only slates, but grits and greenstones, both of which have under-



gone more or less contact alteration. The grits have been more or less fritted and sometimes form true quartzites; as they are essentially silica rocks their mineral composition is as a rule unaltered, but a quartzite was cut in Roskear Shaft composed of quartz grains with fused edges and minute radiating needles of actinolite.

The greenstones as a rule have been altered to garnetiferous rocks, the garnet occurring as streaks and lenticles associated with pale green pyroxenes, epidote, etc. Another type of altered greenstone is the spotted greenstone of Trevalour quarry, Penzance; which consists of a bleached rock containing spots, composed of hornblende and pyrrhotite with axinite and epidote.

One of the best localities for the study of contact alteration is the coast between Cape Cornwall and Levant, where the granite is bordered by a band composed of alternating slate and greenstone, and the alteration types are to be seen in great variety.

In the Camelford area the Devonian rocks show the effects of contact alteration in a well-defined metamorphic aureole which is over a mile and a half wide in places. Near the granite the slates, which were originally fine micaceous muds, have been sheared and foliated with lenticles of quartz. Further away from the granite there are two important types of altered slate.

1. Spotted slates with much white mica and some andalusite, together with crystals of chloritoid, grains of iron oxide and prisms of rutile. They may be described as chloritoid mica schists.

2. Slates with both dark and white mica in about equal proportions, which occur in lenticles separated by lenticles of quartz. There is a little chloritoid and andalusite white cordierite is a common constituent.

The Delabole slate is the only kind which has been worked for roofing material, the type used being a sericite



phyllite with quartz and a little tourmaline, garnet, and rutile. Other types which occur in this district are ottrelite schist, black quartzite and calc flinta.

In most districts the slates near the granite have not only been subjected to contact metamorphism, but in addition, to the action of vapours and solutions emanating from the granite itself, which results in the two types of alteration being superimposed and often makes the recognition of purely contact-altered types a matter of great difficulty.

The harder types of altered slate and the contact altered greenstones are much used as road metal, while the Delabole slates have been extensively quarried for roofing slate.

## CHAPTER VIII.

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### THE EFFECTS OF THE VOLATILE CONSTITUENTS OF THE GRANITE MAGMA.

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The magma from which the granite consolidated, not only contained the constituents which crystallized to form the essential and accessory minerals of the granite rock but also contained more volatile components which, for the most part, were left in a fluid condition after the granite consolidated, forming a kind of "mother liquor" of the magma.

This residual fluid was afterwards intruded through cracks and fissures bringing about chemical reactions in the surrounding rock, and thus giving rise to the formation of new minerals both in the surrounding rocks and in the fissures themselves.

The evidence for the existence of these volatile components (the so-called fugitive constituents of the magma) is threefold in Cornwall:—

- i. The gas, liquid and solid inclusions in the granite minerals, especially in the quartz.
- ii. The composition of the new minerals formed in the belt of contact alteration round the granite.

The microscopic inclusions in the granite consist of minute cavities containing liquid with gas bubbles and sometimes minute crystals. The composition of the contents of these cavities is varied, the liquid is usually water, sometimes carbon dioxide, while the gases which have been proved to occur include, carbon dioxide, ammonia, nitrogen and hydrogen. The solids existing in



solution and as crystals include:—chlorides and fluorides of sodium, potassium and calcium: sulphates of sodium, potassium, and calcium: carbonates of sodium and potassium: hydrochloric and hydrofluoric acid.

These inclusions must represent minute quantities of the fugitive constituents which have been caught up in the consolidating magma and we may conclude that they give a clue to the composition of these fugitive constituents.

The minerals of the belt of contact alteration include such significant species as tourmaline, axinite, topaz, fluor spar, secondary quartz, sericitic mica, gilbertite mica, zinnwaldite mica, chlorite, kaolin, etc.

These minerals indicate that the fugitive constituents contained the elements fluorine and boron, and water. In fact there is nothing that impresses the mineralogist more than the prevalence of water-bearing minerals in the rocks immediately surrounding the granite.

The results of the action of these fugitive constituents are seen, not only in the rocks surrounding the granite but also in the granite itself and the quartz porphyry dykes, while the pegmatites are especially rich in minerals which bear evidence of this type of action.

The types of contact alteration may be summarised as follows:—

| CHANGE.          | PRODUCTS.                                                                                       |
|------------------|-------------------------------------------------------------------------------------------------|
| Tourmalinisation | ... Tourmaline granite, schorl rock, tourmaline quartz porphyry, tourmaline slate, calc flinta. |
| Greisening       | ... Greisen, topaz-fels, silicified quartz porphyry.                                            |
| Kaolinisation    | ... China clay rock, fuller's earth.                                                            |

Tourmalinisation is a change by which minerals containing aluminium are converted into tourmaline, the borosilicate, while those containing aluminium and lime are altered to axinite. This change converts granites into



tourmaline granites such as luxulyanite, in which the dark mica and more or less of the felspar is changed to tourmaline, which often occurs as clusters of radiating tourmaline needles, the so-called schorl. If the change is complete, the granite has all its felspar and biotite altered and we get a quartz tourmaline rock or schorl rock. This change occurs along the walls of fissures and mineral veins, penetrating the rock on either side for a greater or less distance, so that we get dyke-like bands of altered granite such as the famous Roche Rock. The change may also be traced from its inception to a maximum. Near Trevalgan, between St. Ives and Zennor, the granite shows alteration to schorl rock, the original felspar phenocrysts being represented by areas rich in quartz; this rock passes into one in which the phenocrysts of felspar have only been slightly altered and occur as pink phenocrysts in a base of quartz and tourmaline, the so-called trevalganite; and this type in turn passes into slightly altered granite containing only a few patches of schorl needles. Not only does schorl rock occur as a type of altered granite, but it is also found as a vein filling, varying from a rock composed of coarse-grained quartz and tourmaline to a rock of very fine grain consisting of quartz crowded with minute needles of tourmaline which give it a blue grey colour. This is the "capel" of the Cornish miner and is common in the lower levels of the tin lodes.

That tourmalinisation took place after the intrusion of the quartz porphyry dykes is shown by the fact that they are also altered by this action. All types of altered dyke rock may be seen from those containing a few patches of schorl needles to types in which the alteration of the felspar is complete.

The sedimentary rocks are also altered by the same process. The slates which contain much aluminium silicate have this altered to tourmaline in the neighbourhood of the granite. If the slate was highly aluminous it becomes a



dark brown or black rock composed of tourmaline with a little quartz. If on the other hand, as is sometimes the case, it consists of alternating laminæ of quartz and aluminous material, it is altered to a black and white banded rock composed of alternating layers of white quartz and black or brown tourmaline. This type of alteration is found in the neighbourhood of the granite only and can be seen at its best at Wheal Fortune, near Breage; and Gwennap United Mines, near St. Day; it has often been referred to as tourmaline schist owing to its apparent foliation.

When the slates are calcareous, as is the case with the Devonian slates in the eastern half of the county, the change is of a different character. Instead of tourmaline, the most important pneumatolytic mineral is axinite, accompanied by epidote, pale green pyroxene and garnet. The result is a rock with a flinty fracture with variegated colour containing occasional veins of axinite. This type of altered slate is common between St. Columb and Bodmin, and may be seen in the quarry on the north of the Wade-bridge road half a mile beyond St. Columb Road.

Greisening is a change by which the granite is converted into a rock composed of quartz and white mica as chief constituents. Topaz and tourmaline may also occur, the former mineral sometimes being present in such a proportion as to form a topaz-fels. This change is usually restricted to bands in the neighbourhood of the granite margin which often have a central vein of white quartz and which usually carry metallic minerals such as cassiterite, wolfram, etc. Two ideal localities for the study of greisens are St. Michael's Mount and Cligga Head, near Perranporth. Both places are private, and permission to visit must be obtained from Lord St. Levan, for St. Michael's Mount; and Nobel's Explosive Co., Perranporth, for Cligga Head. The south foreshore of St. Michael's Mount shows a fine section of the granite-slate contact, with numerous greisen bands in the marginal granite. The minerals to be seen on the weathered joint planes and



vein faces include cassiterite, wolfram, chalcocite, topaz, apatite, beryl and many others. The collection of specimens is not permitted and it is to be hoped that visitors will do all they can to preserve this beautiful natural museum.

The exposure at Cligga Head is less easily accessible, being approached by a path down the cliff face which requires a steady head. The slate-granite contact is here almost vertical, and the greisen bands run in the granite parallel to its margin and show a similar series of minerals to those at St. Michael's Mount.

In several localities such as Kit Hill, Hemerdon, near Plymouth; and Lady Gwendoline Mine, Godolphin; greisens have been so highly mineralised as to be worked as ore bodies.

The quartz porphyry dykes have also been subjected to greisenizing action, the dyke exposed on the south of the high road on Sennen Common having been completely silicified as well as partially tourmalinised. A similarly altered dyke occurs near Belowda village, north of the Goss Moors, which was sufficiently rich in cassiterite to be worked for tin.

Greisens are also very common in the china clay areas, where they usually carry yellow gilbertite mica.

In many instances greisens show the effects of tourmalinisation, which seems to have occurred before the greisenizing.

The third change, kaolinisation, is for the most part confined to the granite itself and is shown at its best in the western half of the St. Austell granite area, where there are large areas of granite which have undergone more or less complete kaolinisation, that is to say, the felspar of the granite has been altered to kaolin and silica, so that the hard granite has become a soft incoherent rock which can be sluiced down by a stream of water or a monitor.



There are still some who attribute this change to the action of meteoric water, but while it is possible for kaolinisation to be brought about by meteoric water, those who have the most intimate knowledge of the china clay areas believe that the change was the result of the action of magmatic water, the reasons for this belief being briefly as follows:—

1. Kaolinisation in Cornwall is restricted, so far as the china clay areas are concerned, to areas surrounding lode fissures; the run of the china clay pits being determined by the strike of the lodes. Moreover in Cornwall generally the phenomena of kaolinisation are closely associated with lode formation, greisening and tourmalinisation, as can be seen in many localities, but especially in the Balleswidden Mine, St. Just; or the Bunny Mine, St. Austell.

2. China clay rock shows an increase in the completeness of the kaolinisation with depth. Thus as the clay pit goes down the quality and quantity of the clay improve. Also in some localities china clay rock is found under a cover of unaltered or slightly altered granite.

3. Mr. J. M. Coon states that the microscopical character of the Cornish china clay is quite different to that of clay of undoubted meteoric origin.

4. In Cornwall the conversion of felspar to china clay seems to be a process of two stages, the first being the conversion of felspar to gilbertite, while the second is the conversion of gilbertite to china clay. This is well shown in the pits of the Burngullow Beacon district, where specimens can be obtained showing the felspar altered to gilbertite as well as to mixtures of gilbertite and kaolin and completely to kaolin. As gilbertite is recognised as being due to solutions arising from the magma, it follows that if this is a preliminary stage in the formation of china clay the latter must also be due to magmatic solutions.

5. The complete absence of carbonates and sulphates from the Cornish china clay is not compatible with its



having been formed by the action of meteoric water, while the common occurrence of fluor-bearing minerals such as gilbertite and topaz indicates magmatic vapours as the agents of alteration.

The china clay rock is traversed by veins of schorl rock, greisen and quartz, which often carry cassiterite. To these veins the name "stent" is given locally: they stand out prominently in the clay pits, where they form valueless material which has to be got rid of, though some carry sufficient cassiterite to be worked by tributers.

If the kaolinisation is not complete it will be observed that the large crystals of felspar have resisted change to some extent and weather out as idiomorphic crystals, often showing twinning of the various types: to these the clay-worker gives the name "pig's eggs."

Though kaolinisation is most extensive in the St. Austell granite area and the best clay is produced there, all the granite outcrops show kaolinisation to some extent. In the Land's End granite area china clay is worked at Balleswidden near St. Just, and at pits near Towednack; while it was formerly worked on the north of Castle an Dinas, and has been proved to exist at Ding Dong. Old clay pits are found on the Godolphin and Tregoning granite though they have not been worked for some time. China clay has been proved near Menherion on the Carnmenellis outcrop, and there is an area of kaolinised granite at St. Day on the Carn Marth outcrop. In the Bodmin Moor granite kaolinisation is also found in the western area of the outcrop near Blisland, Cardinham and Temple, but the cost of carriage has always been a great obstacle to the economic working of the deposits. In this area there is also evidence that some of the kaolinisation is due to the action of meteoric water, as the rock below the peat bogs of the hollows is usually kaolinised to a moderate depth. Dartmoor, in the neighbouring county, also has china clay areas in the south of the granite outcrop near Hemerdon. Again in many of the mineral areas where the lodes cut



the granite that rock is often kaolinised for a width of a few feet on each side of the lode which, although of no economic importance, is suggestive of the close connection between lode filling and kaolinisation.

In addition to the kaolinised granite there occurs in the western part of the china clay area a type of granite known as china stone. It is essentially a granite free from iron-bearing minerals and containing more or less fluorspar. It occurs in a very irregular manner, apparently as segregations in the granite and has been considered by some to be a type of altered granite, while others think it to be original. Further work is necessary to settle the point with certainty. Unlike china clay rock it is as hard as fresh granite and often shows no signs of kaolinisation. The component minerals are quartz, felspar (largely albite), purple fluorspar, gilbertite, lepidolite and topaz. It is quarried in the ordinary way and ground to a fine powder, being used for porcelain making its value depending on its low melting point ( $1200^{\circ}$  C.) due to the fluorspar and its conversion on melting into a colourless or white glass. It occurs in three types, the "hard purple" with much fluorspar and unaltered felspar, the "mild purple" with less fluorspar and slightly altered felspar, and "white" with little fluorspar and much kaolinised felspar. The first type is most highly valued. There is a fourth type called "buff" china stone which is like the "white" except that it is coloured by iron oxide and is therefore of little commercial value. One of the best localities to see china stone is Tregargus Quarry, near St. Stephen's, where the getting, grinding and drying can be inspected.

Not only has the granite been subjected to kaolinisation but the quartz porphyry dykes frequently show its effects. In these, however, it is the felspar phenocryst that is most easily altered, the finer felspar being too closely locked up with quartz to be readily accessible to vapours or solutions. At various localities, notably St. Agnes and Baldhu, there are quartz porphyry dykes in which the felspar pheno-

crysts have been altered to powdery china clay which washes out of the exposed rock, leaving negative pseudomorphs of felspar.

The clay slates seem also to have undergone a similar change. At Treamble on the Great Perran Iron Lode, the slate on each side of the lode has been altered to an earth having similar properties to those of fuller's earth. The material has the cleavage of slate, but is soft and unctuous and has lost its iron, magnesia and lime almost completely. It has been observed in smaller bodies along other iron lodes of the district and probably occurs at other points along the Perran Iron Lode.



## CHAPTER IX.

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### THE LODES OF CORNWALL.

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Cornwall from very early times has been noted for its production of tin and copper, and notwithstanding the long period during which mining operations have been carried on, the Cornish tin mines are still producing considerable quantities of that metal. Not only tin and copper, but arsenic, wolfram, lead, zinc, silver, uranium, radium, iron, manganese, antimony, nickel, and cobalt have been produced in the county.

The lodes occupy fissures in the granite and overlying slate which resulted from crustal movement, and Moissenet\* determined the directions of the lodes of the county and classified them in groups, each associated with a period of earth movement, which are illustrated in fig. 5, from which it will be seen that there are four main directions, while the lodes running north of east are by far the most numerous and also the most ancient. This predominant direction of the lodes is especially clearly seen on the one-inch geological map of Camborne and Falmouth, in which district the lode directions are very uniform, while in other districts the lode directions are more varied.

The lode fissures cut the granite and the elvan dykes as well as the slate and greenstone: the lodes are therefore younger than all of these rocks; at the same time they are not much younger than the acid intrusions as will be seen later on. As a general rule the lodes in the slate dip away from the granite so that in the Camborne-Redruth

\* Lodes of Cornwall, Moissenet trans. by Collins, 1877.

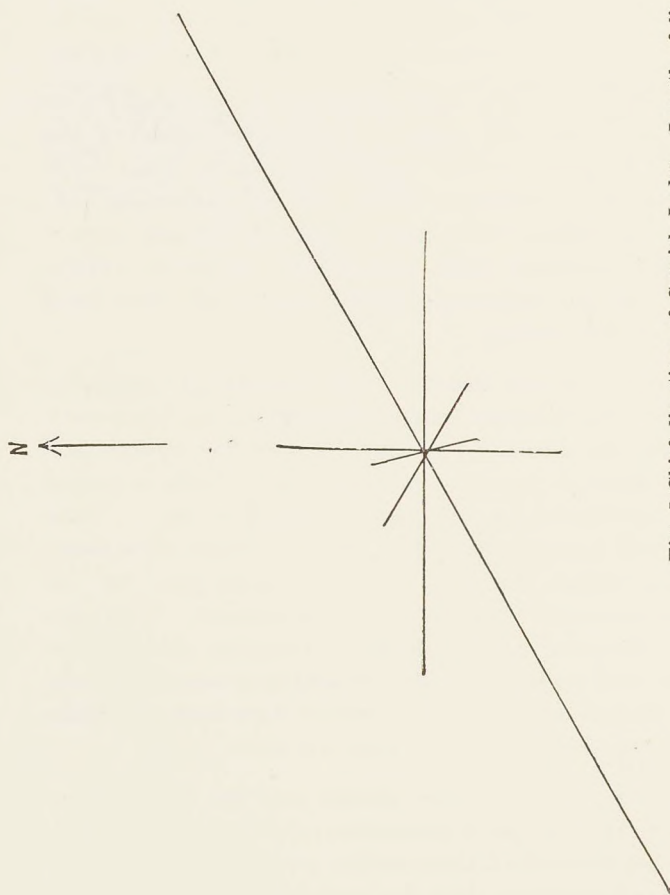


Fig. 5 Chief directions of Cornish Lodes. Length of line proportional to number of lodes,



district the majority of the lodes in the slate dip north, away from the granite outcrop, but on approaching the granite in depth many lodes deflect and dip into the granite at the contact. As a rule the lodes striking east and west are cut and often faulted by those striking north and south, in fact in the Camborne-Redruth area the north and south fissures are often faults, or as the Cornish miner terms them, cross courses, without mineral contents. It is also usual for the east and west lodes which dip south to cut and sometimes fault those which dip north. Most of the lodes are themselves fault fissures, which is shown by the dislocation of the country rock, the brecciation of the lode walls and the nature of the fissures. They have as a rule a steep dip or underlie which is often within  $30^\circ$  of the vertical: lodes with a more gentle dip are termed "flat" lodes, thus the Great Flat Lode to the south of Carn Brea has a dip of about  $45^\circ$ .

There is abundant evidence to show that the metallic minerals of the lodes were derived from the granitic magma. Thus there are frequent instances, of veins at points considerable distances above the granite surface, being filled with granitic material intermixed with the usual lode minerals.\* Many of the lode minerals are such as are only formed under conditions of high pressure and high temperature, such, for example, as tourmaline and topaz.

Many have been the theories put forward to account for the filling of the fissures in the granite and country rock of Cornwall with metallic minerals. Among the earliest was the notion that the lode contents were brought there by meteoric water percolating from above, then followed the lateral secretion theory which gave the credit to water passing laterally from the country rock to the lode fissures, leaching the metals from the country rock and depositing them in the fissures in one form or another. There is also the theory which gives electrolytic action credit for ore

\* Geol. Mag., 1924. Trans. Corn. Inst. Eng., 1925.



deposition, and many other theories explanatory of one phase or another of ore deposition. From the standpoint of to-day it can be seen that these theories developed one after the other as mining operations became deeper and deeper. The meteoric theory explained many features of the upper parts of the lodes, while the lateral secretion theory was applicable to a certain extent in explaining the phenomena met with in the secondary enrichment zone.

When deeper levels were reached it, however, became evident that there was a close connection between the filling of the lodes and the intrusion of the granitic magma. This is shown by phenomena met with in the lodes and the neighbouring rocks, of which the following are the most important :—

The lode contents frequently show included magmatic material, and this at points well above the granite, so that its presence cannot be explained by the inclusion of fragments of country rock in the lode.\* For example, in New Cooks section, South Crofty Mine, at a point 100 feet above the granite surface a lode showed quartz, wolfram, stannite and mispickel, with intergrown granite material.

The lodes are associated with alteration in the country rock resulting from the action of magmatic vapours and solutions. Thus the lodes at Balleswidden Mine and Bunny Mine showed a gradual passage from the lode into the country rock as follows :—lode material, greisen, tourmaline granite or schorl rock, kaolinised granite. In other cases the lode fissure was obviously the channel from which the vapour and solutions percolated into the surrounding rocks. As noted above kaolinisation is frequent along the walls of lodes in the granite, while greisenizing is almost an invariable feature along the walls of lodes traversing the granite.

The lodes contain minerals which can only crystallize under conditions of moderately high temperature accom-

\* Geol. Mag., 1924: Mining Mag; Trans. Corn. Inst. Eng., 1926.



panied by high pressure, for example, tourmaline, topaz, and felspar. Thus the fissure at the time of the deposition of its contents must have been accessible to magmatic material, but not open to the surface, as the pressure must have been greater than would be produced by the head of solution in it.

The metallic minerals of the lodes are arranged in a series of zones and their position is determined by the level of the granite surface, which, at the time when the lode filling took place, must have determined the temperature of the rocks above it.

These primary zones have been investigated by various authors, the results being given in the table below:—

TABLE 1.

| <i>MacAlister.</i>                                                                | <i>Cronshaw.</i>                                                               | <i>Dewey.</i>                                                                                | <i>Davison.</i>                                                                                             |
|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
|                                                                                   | 9. Calcite                                                                     |                                                                                              |                                                                                                             |
|                                                                                   | 8. Pyrite<br>Hæmatite<br>Siderite<br>Quartz<br>Fluorite                        | 4. Carbonates of<br>Iron and<br>Manganese                                                    | 6. Hæmatite<br>Limonite<br>Siderite<br>Pyrite and<br>Marcasite<br>Pyrolusite                                |
| 3. Galena<br>Blende<br>Pyrite<br>Ni, Co, Cu<br>Arsenopyrite<br>Quartz<br>Chlorite | 7. Galena<br>Blende<br>Chalcopyrite<br>Fluorite                                | 3. Sulphides of<br>Antimony<br>Sulphides of<br>Pb + Ag,<br>giving place<br>in depth to<br>Zn | 5. Galena<br>Blende<br>Pyrite<br>Quartz<br>Dolomite<br>Chalcedony<br>Minerals of U,<br>Ni, Co<br>Fluorite   |
| 2. Copper<br>Tin                                                                  | 6. Chalcopyrite<br>Quartz<br>Fluorite<br>Tourmaline<br>Cassiterite<br>Chlorite | 2. Sulphides of<br>Copper<br>+ Wolfram<br>+ Tin                                              | 4. Chalcopyrite<br>Wolfram<br>Arsenopyrite<br>Quartz<br>Fluorite<br>Pyrite<br>Jasper                        |
|                                                                                   | 5. Chlorite<br>Tourmaline<br>Cassiterite<br>Arsenopyrite<br>Quartz<br>Fluorite |                                                                                              | 3. Chalcopyrite<br>Wolfram<br>Arsenopyrite<br>Quartz<br>Cassiterite<br>Chlorite                             |
|                                                                                   | 4. Fluorite<br>Tourmaline<br>Cassiterite<br>Arsenopyrite<br>Quartz             |                                                                                              |                                                                                                             |
| 1. Tin                                                                            | 3. Cassiterite<br>Arsenopyrite<br>Tourmaline<br>Quartz<br>Fluorite             | 1. Oxide of Tin<br>+ Wolfram                                                                 | 2. Cassiterite<br>Arsenopyrite<br>+ Wolfram,<br>near granite<br>cupolas<br>Chlorite<br>Tourmaline<br>Quartz |
|                                                                                   | 2. Cassiterite<br>Arsenopyrite<br>Quartz<br>Tourmaline                         |                                                                                              | 1. Cassiterite<br>Quartz<br>Tourmaline<br>Specular<br>Hæmatite                                              |
|                                                                                   | 1. Quartz<br>Wolfram<br>Arsenopyrite<br>Cassiterite<br>Felspar<br>Tourmaline   |                                                                                              |                                                                                                             |



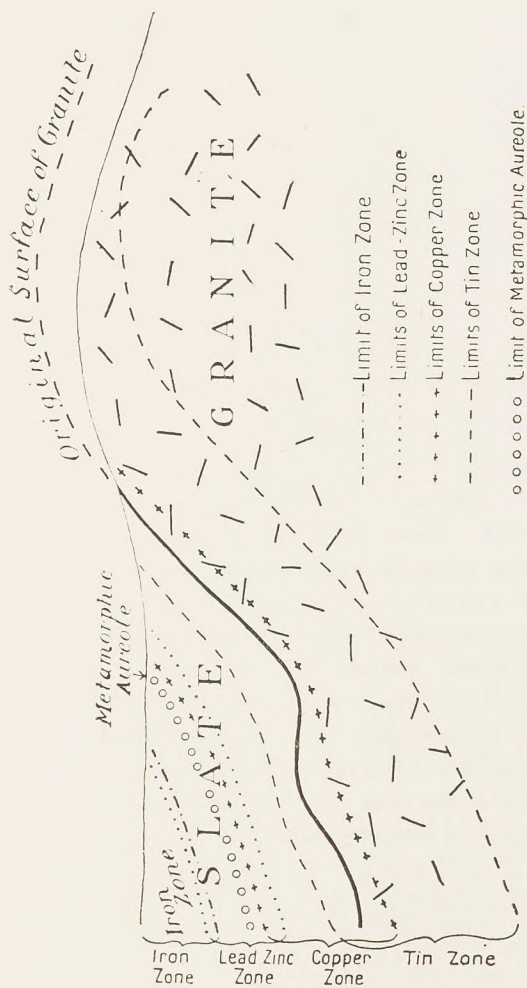


Fig. 6 Cornish Mineral Zones.

The tin zone is situated mainly in the granite. It extends from a depth of at least 4000 feet in the granite to a few hundred feet above the granite surface.

The copper zone extends from a shallow depth in the granite to some 1500 feet above its surface but does not extend beyond the limits of the metamorphic aureole.

The lead zinc silver zone extends from inside the metamorphic aureole to well beyond its outer limit.

It will thus be seen (fig. 6) that the zone at which the land surface truncates the lode depends on the position of the lode relatively to the granite surface. If the slope of the granite underground is gentle the belt of slate surrounding the granite in which the tin zone will occur at surface will be wide, while if the granite slopes steeply the various zones will have narrow outcrops.

The contents of the lodes are not quite so simple as will at first appear, however. Where the lode outcrops meteoric water finds its way downwards, leaching and oxidizing the contents from surface down to the level of permanent saturation, where the substances dissolved above are re-deposited in another form, thus enriching the lode with those metals which were dissolved. Thus superimposed on the primary zones already described we have zones of oxidation and secondary enrichment, often resulting in a lode of complex composition. The following table illustrates the way in which these secondary changes affect the various primary zones.



# RESULTS OF SECONDARY CHANGES ON PRIMARY ZONES.

|                                 | <i>Tin Zone.</i>                                                                                                                                          | <i>Copper, Arsenic, Wolfram Zone</i>                                                                                               | <i>Lead, Zinc, Silver Zone.</i>                                                                           |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
| Zone of Oxidation and Leaching. | Oxidation of sulphides to sulphates with formation of iron oxide hence red 'gossan' and enrichment of lode by removal of minerals which do not carry tin. | Solution of copper and arsenic minerals. Alteration of wolfram to scheelite if lime is present.                                    | Solution of lead and zinc minerals to form an impoverished 'gossan.'                                      |
| Zone of Enrichment.             | Possible deposition of 'wood tin' resulting from solution of stannite.                                                                                    | <i>Upper part.</i>                                                                                                                 |                                                                                                           |
|                                 |                                                                                                                                                           | Deposition of carbonates, arsenates and phosphates of copper (malachite, olivenite, libethenite) cuprite, native copper, scorodite | Deposition of such minerals as cerussite, anglesite, calamine, horn silver, and complex silver compounds. |
|                                 |                                                                                                                                                           | <i>Lower part.</i>                                                                                                                 |                                                                                                           |
|                                 |                                                                                                                                                           | Deposition of secondary sulphides e.g. bornite, chalcocite, tetrahedrite, etc.                                                     |                                                                                                           |

All the lodes were not, however, filled at the same time; as was mentioned above, the north and south lodes cut and faulted the east and west lodes and were apparently not in existence when the filling of the latter began, as they show the lead-zinc only, the tin and copper having ceased to arrive before these fissures were formed.

The character of the veinstone varies considerably with the zone from which it was taken and the depth from surface. In the lower part of the tin zone the veinstone is usually brecciated, often consisting of brecciated fragments of quartz crowded with minute needles of tourmaline and blue grey in colour cemented by quartz, tourmaline and cassiterite. Such veinstone can be collected on the waste heap of the disused William's shaft, Dolcoath, and is termed "Capel" by the miners. Higher up the lode chlorite begins to take the place of tourmaline and the lode structure becomes coarser, brecciation being still common. Above this the lode begins to show copper minerals with arsenic and possibly wolfram, but the distribution of the wolfram is peculiar, as it seems to be confined to the upper part of the tin zone, just inside and outside the granite, and is especially likely to occur in the neighbourhood of ridges in the granite surface.\* An interesting case of the alteration of wolfram to scheelite occurred in the Roger's lode of the old East Pool Mine, where the wolfram crystals had partly altered to scheelite, the lime having been derived from a greenstone sill some distance above.

At still higher points in the lodes comb structure appears and is especially characteristic of the lead-zinc veinstones: fluorspar is of irregular distribution, but is usually found in the tin, copper and lead-zinc zones, often in large quantities. At Parc-an-chy mine, near St. Day, the veinstone consists of a granite saturated with purple fluorspar.

\* Mining Mag., 1921.



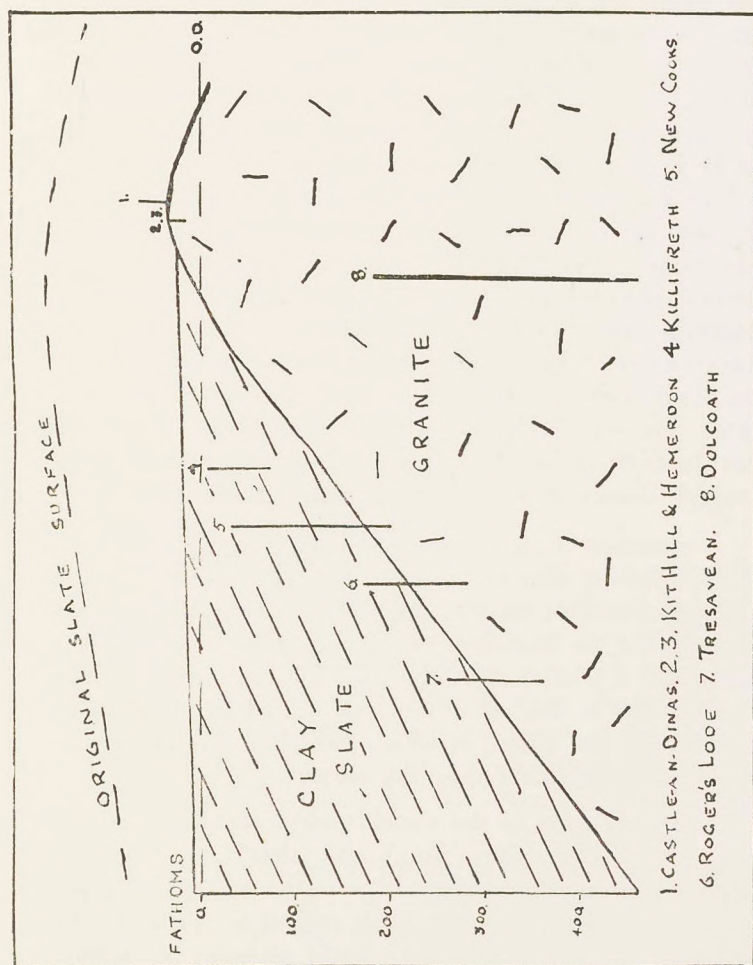


Fig. 7 Diagram to Illustrate Relation of Lodes to Granite.

Taking the above facts into consideration, it will be seen that the character and contents of a lode are largely determined by its position relative to the granite surface. Fig. 7 illustrates diagrammatically the position of several mines relatively to the granite. Thus, Castle an Dinas is situated on the crest of a small granite boss or cupola and its lode contains coarsely crystallised wolfram and cassiterite and some mispickel. Killifreth Mine was worked in the slate above the granite and its lodes carried cassiterite, wolfram, chalcopryite, etc., with chlorite. New Cook's lodes were worked from the slate into the granite, as was the case with the old East Pool Mine, the lodes containing cassiterite and mispickel and wolfram with chalcopryite. Tresavean was similar, but rather deeper, while Dolcoath was deep in the granite and in its deeper levels contained tin as the only important metal. The New Cook's and East Pool (Roger's lode) also passed downwards into lodes in which cassiterite was the essential metallic mineral.

Veinstones of the copper and lead-zinc zones are often highly vesicular near the surface, the result of the removal of the more soluble minerals by leaching. There is evidence to show that the lode fissures were in many cases filled by stages, and it is often possible to distinguish the generations of cassiterite in the veinstone, one set of veinlets cutting and faulting the other, in which case the younger vein is usually paler in colour than the older.

The deposition of the metallic minerals was attributed to pneumatolytic action by Vogt,\* that is to say, the metallic minerals were extracted from the magma by means of volatile substances above their critical temperature, the most active agents in the case of acid magmas being fluorine, boron, phosphorus and steam, which are concentrated in the residual fluid of the consolidating granite carrying with them the metallic constituents.

\* Vogt. Zeit. f. Prakt. Geol. 1884-90, Kemp. Trans. Amer. Inst. Eng. 1901.



The term pneumatolysis seems a rather unhappy one as it is doubtful if there was any actual evolution of vapour, but rather an intrusion of watery magma highly charged with these volatile constituents.

In fact the lode fillings may be considered as being pegmatites, which have been modified by differentiation and have thus had the metallic element concentrated in them.

As a result of the action of these volatile agents the following minerals are characteristic of lode formations in granite regions :—

Tourmaline, topaz, axinite, fluor mica, apatite, garnet, fluor-spar, chlorite, quartz, and iron pyrites. Some of these minerals occur as vein constituents, while others occur in the altered country rock. Arrhenius\* shows that metals like tin, tungsten, copper, zinc and iron can exist together independent of one another; tin, tungsten, copper, etc., being liberated at high temperatures, while lead, zinc, etc., are only liberated at low temperatures.

The metallic minerals are not distributed evenly along the strike of the lodes but occur in "shoots" running diagonally down the dip of the lode, so that in following the lode along its strike rich and poor areas alternate. This can be seen in mine sections which show the worked out stopes. These shoots are often the result of the presence of fissures intersecting the lode, while in other cases they seem to be due to variation in the character of the country rock.

An important factor which affects the value of the veinstone is the size of the cassiterite crystals or grains present in it. As the concentration of the ore is entirely carried out by mechanical processes cassiterite of fine grain is very liable to pass over with the lighter waste material, so that the percentage recovery of fine-grained cassiterite is bound to be lower than that of a coarse-grained tinstone.

\* Zur Physik des Vulkanismus, 1900.

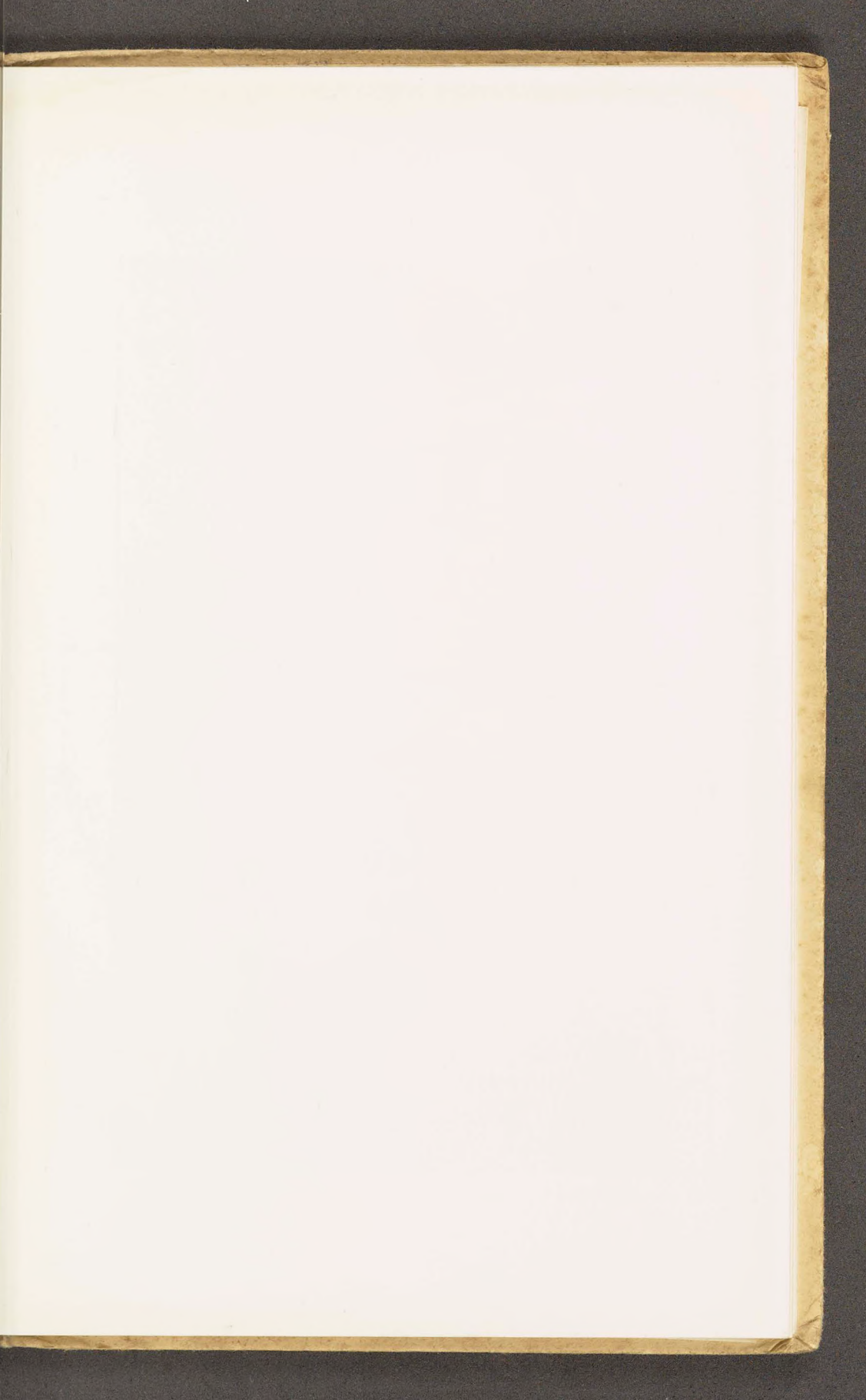
As a broad general rule the size of the cassiterite crystals usually diminishes with increasing depth, so that not only are the deeper parts of the lodes more costly to work on account of their position but the percentage recovery is likely to be less.

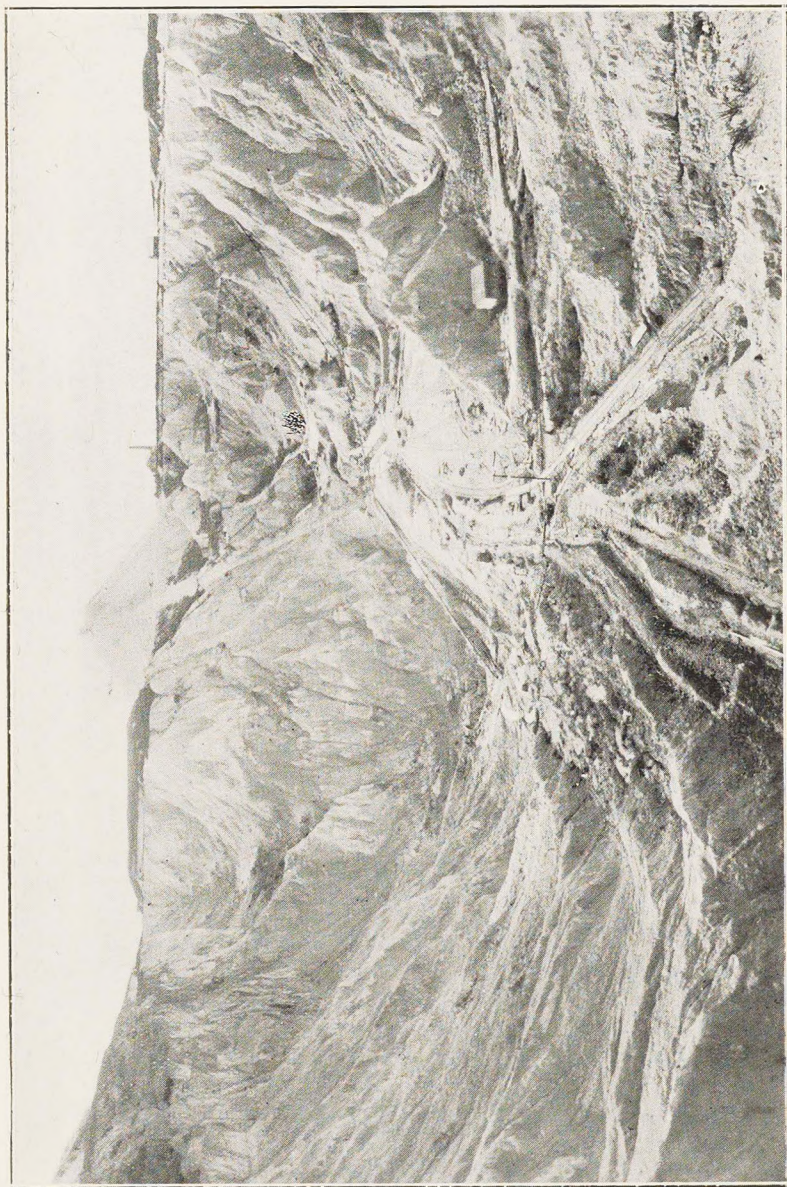
There are, however, other types of deposit besides fissure lodes proper. Stock works consisting of a block of ground occupied by numerous closely placed narrow lodes, such that the lodes and intervening country rock can be taken out bodily as ore, were worked at Mulberry Mine, Lanivet; Wheal Fortune, Breage; and Magdalen Mine, Ponsanooth. Mineralised, greisens formed the ore body at Parc an Chy Mine, St. Day, and Lady Gwendoline Mine, Godolphin, while mineralised quartz porphyry dykes were worked at Parbola Mine, Gwinear; Wheal Bray, Scorrier; Creeg Brawse Mine, Chacewater; and Wheal Budnick, Perranporth; while the great Perran iron lode consists of a fissure sometimes 60 feet wide filled with siderite in its upper part and passing down into a lead-zinc vein.

TABLE 4.  
MECHANICAL ANALYSES OF VEINSTONES.

| Locality of Sample.                                  | Quartz. | Muscovite. | Tourmaline. | Chlorite. | Fluorite or<br>Topaz.  | Pyrite. | Arsenopyrite. | Cassiterite. |
|------------------------------------------------------|---------|------------|-------------|-----------|------------------------|---------|---------------|--------------|
|                                                      | %       | %          | %           | %         | %                      | %       | %             | %            |
| Greisen, Lady Gwendoline .                           | 42      | 28         |             |           | Topaz<br>5             |         |               | 2            |
| Greisen, Parc-an-chy Mine .                          | 40      | 18         |             |           | CaF <sub>2</sub><br>25 |         |               | 2            |
| Roskear Shaft, average of 4<br>samples . . . . .     | 31      | 1.5        |             | 44        | CaF <sub>2</sub><br>2  | 6       |               | 1            |
| Wheal Kitty, average of 4<br>samples . . . . .       | 38      |            | 20          | 45        |                        | 1       |               | 2            |
| Geevor Mine, average of 3<br>samples . . . . .       | 60      |            | 35          |           |                        |         | 1.0           | 1.3          |
| South Crofty Mine, average of<br>3 samples . . . . . | 52      |            | 41          | 2         |                        |         |               | 0.8          |
| Polhigey Mine, average of 3<br>samples . . . . .     | 47      |            | 45          |           |                        |         |               | 0.8          |
| Jantar Mine, average of 3<br>samples . . . . .       | 51      |            | 42          |           |                        |         |               | 1.2          |
| Levant Mine, average of 4<br>samples . . . . .       | 38      |            | 12          | 16        |                        | 10      | 16            | 1            |







Photo—Russell, St. Austell.

CHINA CLAY PIT.



## CHAPTER X.

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### THE CHINA CLAY DEPOSITS.

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The genesis of the China Clay deposits has been discussed in Chapter VIII. but the working of the clay is such an important industry that it is desirable to give some account of the way in which the clay is extracted and purified as well as the uses to which the material is put.

As pointed out above the deposits of china clay lie along the strike of groups of fissure lodes consisting for the most part of greisen or schorl rock carrying variable proportions of cassiterite but sometimes very rich in that mineral. These veins are hard compared with the surrounding clay rock and are known as "stent" veins. Near these veins the kaolinisation of the granite is, as a rule, more complete than at a distance, while the completeness of kaolinisation also increases with depth.

The proportion of china clay in the clay rock varies from 10% to 35% and this clay yields on dressing variable proportions of the three grades of clay which are marketed. These grades are known as Paper or Bleaching Clay, Potting Clay and Mica Clay and each is graded into a number of qualities which sell at different prices. For instance paper clay sells at prices varying from 35/- to 65/- a ton; potting clay from 25/- to 50/- a ton and mica clay from 16/- to 28/- a ton. These prices are much higher than the prices of ten years ago as is seen below :—

PRICES OF CLAY IN 1920 AND 1930 COMPARED.\*

| Quality.         | Price per ton 1920. | Price per ton 1930. |
|------------------|---------------------|---------------------|
| Bleaching ... .. | 25/- to 32/6        | 35/- to 65/-        |
| Potting ... ..   | 18/6 to 24/-        | 25/- to 50/-        |
| Mica Clay ... .. | 10/- to 16/-        | 16/- to 28/-        |

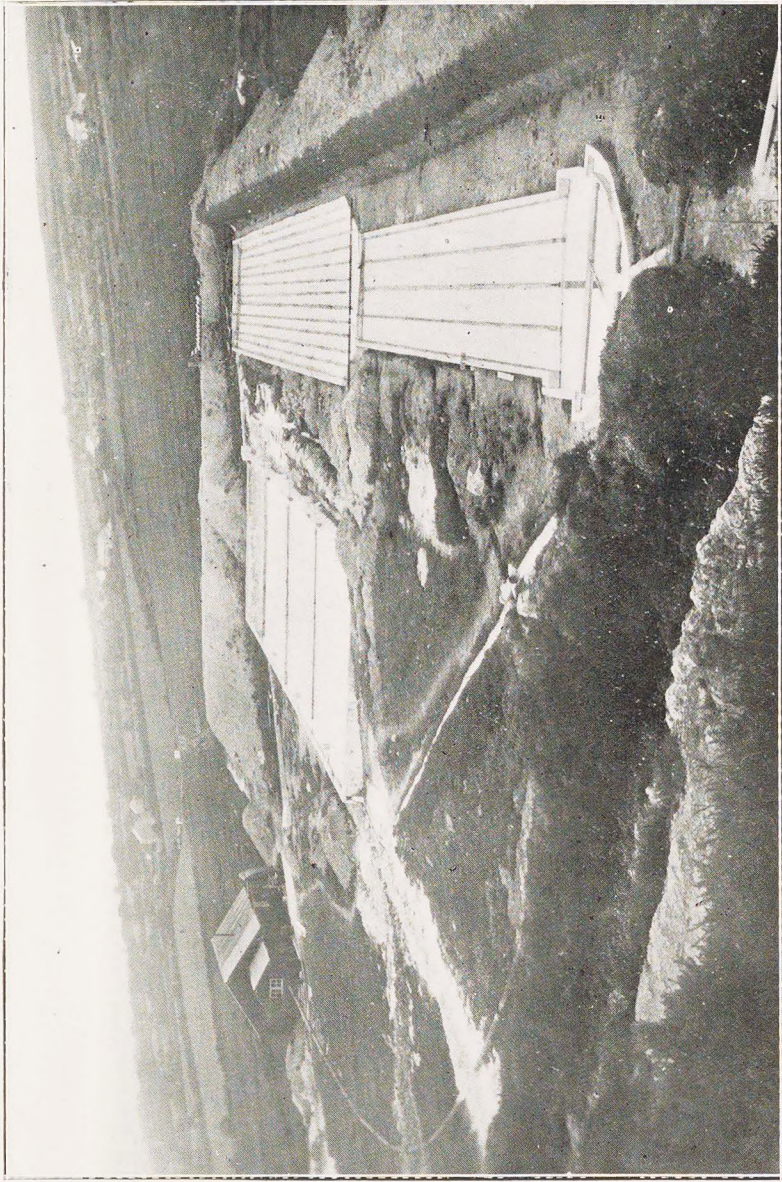
\* Figures supplied by the Editor of the St. Austell Guardian.

China clay is worked in open pits which in some cases are over 300 feet deep. The clay rock is disintegrated by a stream of water under great pressure delivered through a monitor. The water breaks up the clay rock and washes the sand and clay to the bottom of the pit where the sand is allowed to settle in a rectangular tank with a hopper bottom, while the clay and fine sand run over with the water which is pumped to the surface. The coarse sand from the pit is trammed to the top of the pit and tipped to form those white conical heaps which are such a feature of the china clay areas. Some of this sand is used in making concrete blocks, but the supply of sand is much greater than the demand for blocks so the waste heaps continue to grow in size and number.

The water which has been pumped to the surface carries the clay and some fine sand. The stream is then run through long narrow channels, called mica drags, with a semicircular pit at their upper end; the first series of channels discharge into a second semicircular pit and then into a series of channels three times the number of the first series. The stream discharges through fine wire gauze which catches any floating material.

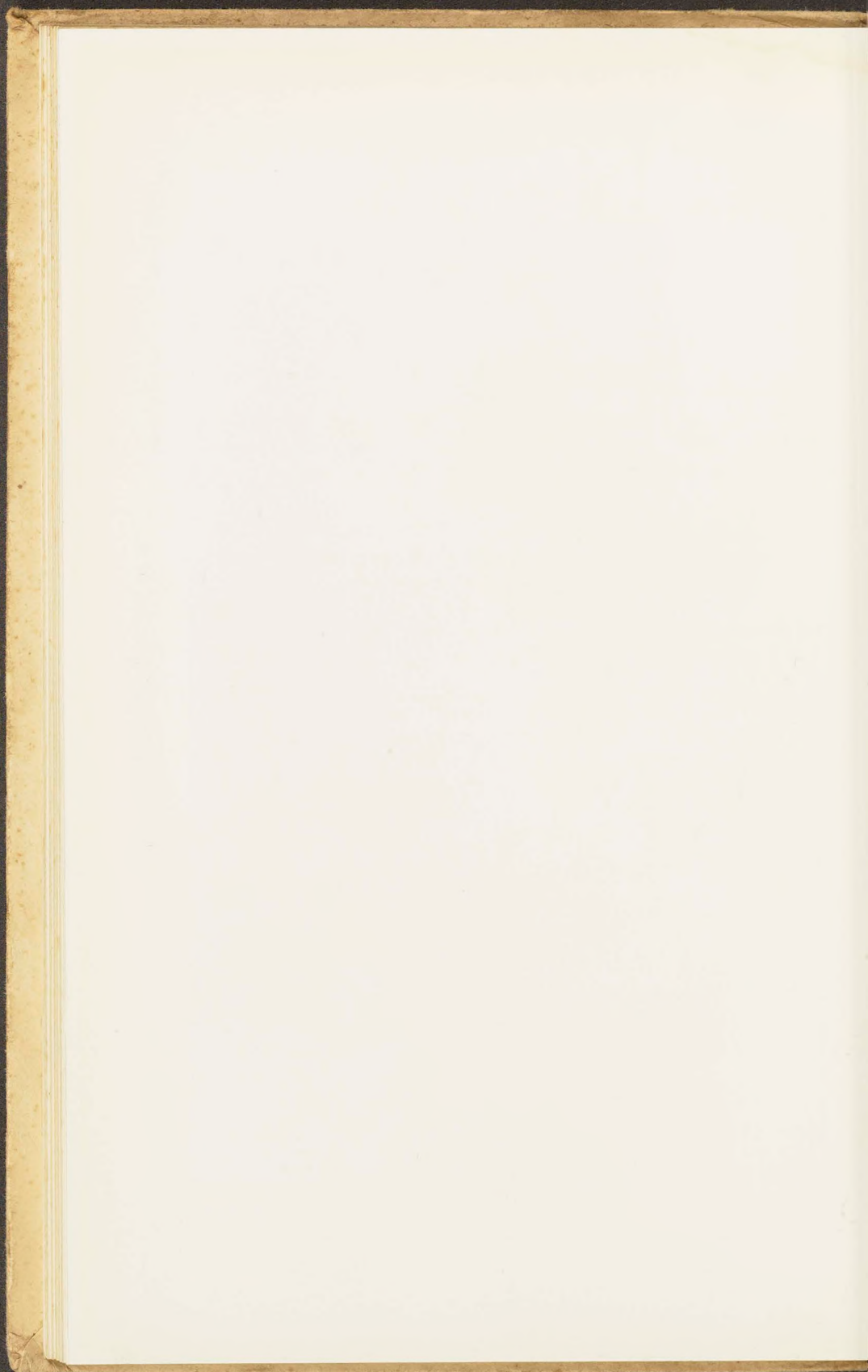
In the first series of channels and in the pits, fine sand and some mica clay is deposited which is sometimes rewashed to recover the mica clay. In the second series of channels mica clay is deposited and this is washed into settling tanks and then to the drying kiln.





Photo—Russell, St. Austell.

**MICA DRAGS AND SETTLING PITS.**





The stream from the mica drags runs into large rectangular, concrete, settling pits where it settles to a consistency of about 35% clay, 65% water.

The clay is now purified and it only remains to dry it. The drying is done in a drying kiln which is, when possible, built alongside the mineral railway, the clay being washed there through a pipe line.

Behind the drying kiln are large rectangular settling pits (120 ft. x 60 ft. x 9 ft.) in which the clay is allowed to settle till it is about half clay and half water. It is then trammed on to the drying pan, a shallow rectangular pit floored with fire clay tiles and heated below by hot air. When dry the clay is transferred to the linhay, a floor some 10 feet below the pan, where it is stored till it is shipped.

The sales of clay are very considerable and the market is steady but for seasonal variation. No clay can at present compete with the best quality clay from the West of England.

CHINA CLAY EXPORTS 1929.

| Destination.        | Tons.   | Value.     |
|---------------------|---------|------------|
| United States ...   | 302,419 | £651,557   |
| Belgium ... ..      | 68,612  | 130,086    |
| India ... ..        | 32,257  | 105,496    |
| Germany ... ..      | 41,823  | 90,129     |
| Netherlands ...     | 43,619  | 94,017     |
| France ... ..       | 46,332  | 85,536     |
| Italy ... ..        | 24,709  | 63,609     |
| Sweden ... ..       | 24,772  | 53,897     |
| Spain ... ..        | 17,189  | 42,579     |
| Norway ... ..       | 14,659  | 24,273     |
| Other countries ... | 34,953  | 83,396     |
| Totals ...          | 661,368 | £1,424,430 |

## CHAPTER XI.

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### THE SECONDARY AND TERTIARY ROCKS OF CORNWALL.

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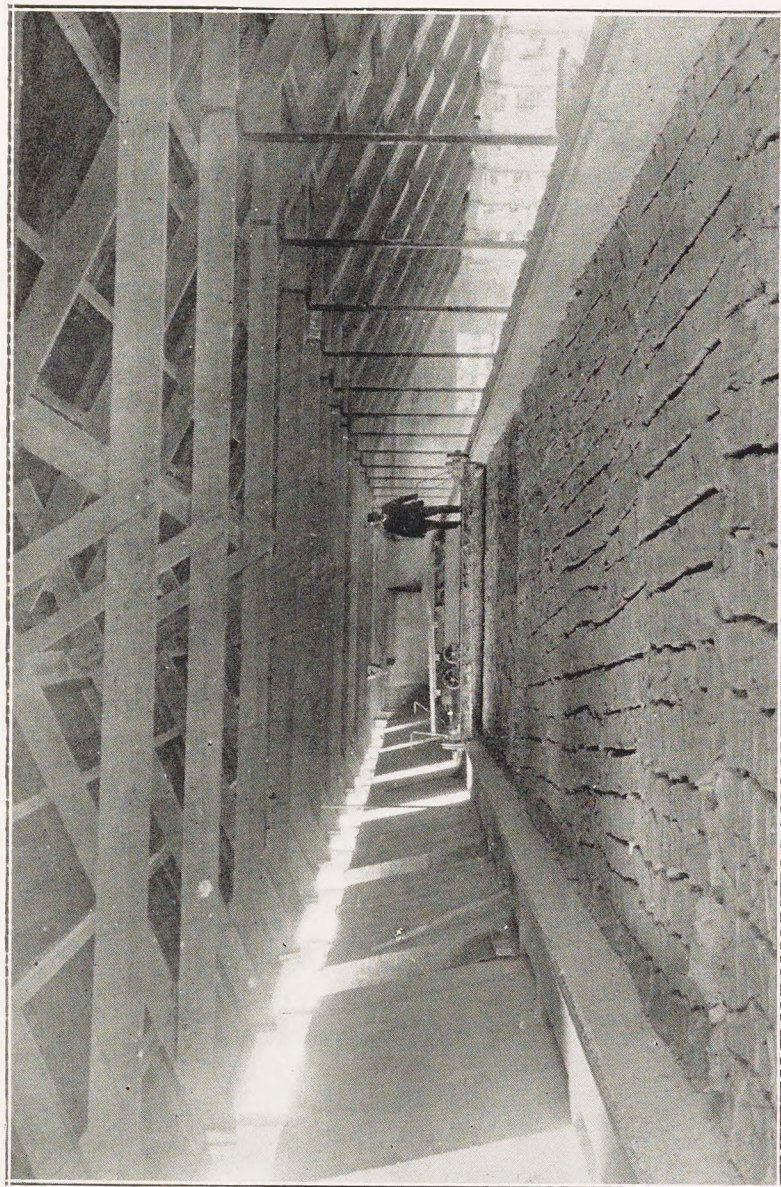
The geological history of Cornwall is practically a blank from the deposition of the Culm Measures, and subsequent intrusion of the granite, to Tertiary times. There is, however, in the east, one occurrence at Cawsand which consists of a patch of conglomerate or breccia on the beach\* which includes fragments of crinoidal limestone, Staddon grit, quartz and of a trap rock which is near the breccia outcrop. The breccia has been considered to be of Triassic age and the occurrence of a block of breccia in Drake's Island and veins of red sandstone in the Plymouth limestone have been cited as confirmation. The trap rock occurs at Cawsand and near Withnoe and shows two varieties of texture, one rhyolitic with flow structure, and the other rubbly in character with crystals of felspar.

The Tertiary rocks are represented by beds of fossiliferous sands and clays at St. Erth which are worked for moulding sand. They lie on sloping ground at a height of 100 feet above sea level, and have yielded 250 species of marine shells with a great variety of foraminifera. They have been correlated with the Lenham Beds in Kent, in which the percentage of extinct species is about the same.

The beds consist of overlying sand with clay and thick sand below on a bed rock of slate or quartz porphyry. The fossils show that the deposits were laid down in a fair

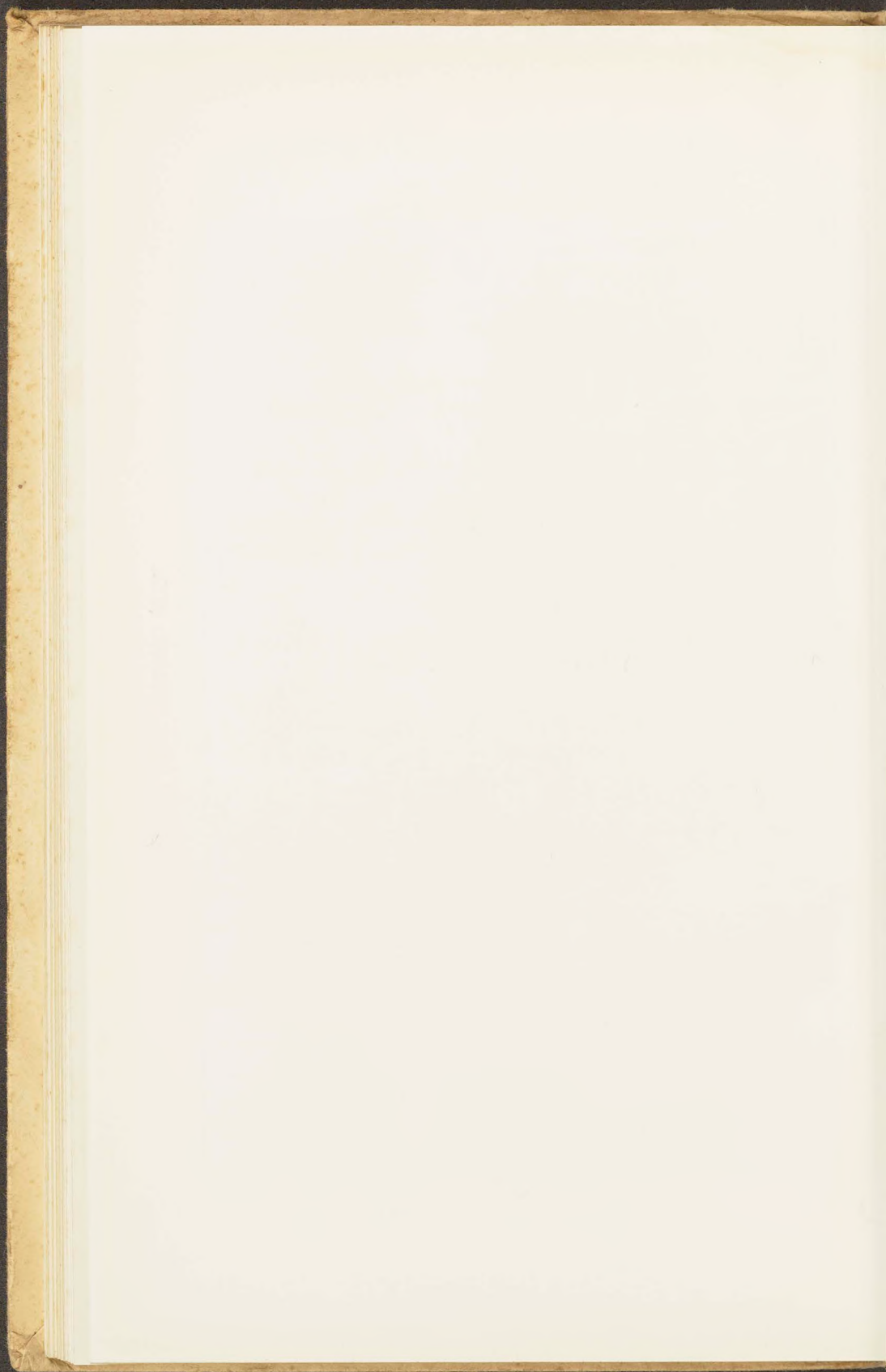
\* Pengelly. Trans. Devon. Assoc., Vol. IX.





Photo—Russell, St. Austell.

CHINA CLAY DRYING KILN.





depth of water as littoral shells are scarce, and the presence of the clay beds indicates fairly still water. As will be seen later, it is probable that the sea level of the time is marked by the shelf of marine denudation which occurs with its upper level at about 430 feet above the present sea level and can be traced round the coast between St. Ives and Zennor, along the North Cliffs to St. Agnes and on the Lizard plateau.

The only pit now working at St. Erth is to the south of the vicarage, and does not yield so many fossils as the pits previously worked to the north: however, the visitor will generally be able to collect a few species in a somewhat fragmentary condition.

Another sand deposit occurs on the north side of St. Erth station at the same level, but it is not worked, and can only be traced by the character of the soil.

At St. Agnes, Polcrebo Downs and Crousa Downs there occur other deposits of sand and gravels, none of which have yet yielded any fossils. The St. Agnes beds lie on the north-west side of the Beacon and run round it in a semicircular outcrop between the 350 feet and 420 feet contours. The deposit consists of Head on grey clay with sandy clay and red sands below. The heavy minerals include tourmaline, zircon, rutile, andalusite, topaz, kyanite, staurolite, and cassiterite; that is, minerals of the local rocks. The clays were formerly worked for miners' "candle clay" and the sands are at the present time worked for moulding and core sand. Polcrebo Downs lie to the east above Nancegollan, the deposit, consisting of quartz pebbles, large and small, which are well water-worn, lying on a bottom of decomposed granite. The heavy minerals include tourmaline, cassiterite, topaz, andalusite, staurolite and zircon and are thus comparable with those of St. Agnes.

Crousa Common lies to the west of St. Keverne in the Lizard plateau and on it occurs a deposit of quartz



gravel with an area of about half a square mile at an elevation of 365 feet. The gravel consists of subangular pebbles of vein quartz in a fine earthy base: no granite or gabbro pebbles occur, but one occasionally meets with pebbles of tourmaline slate. They have been derived from the country to the north and contain only the hardest material of the waste. The gravels seem to have extended further to the west at one time, as traces of them are found on Goonhilly Downs. The heavy minerals of the earthy base include tourmaline, topaz, cassiterite, zircon, rutile, anatase, staurolite, etc.

The close resemblance in the heavy minerals present has led to the correlation of these deposits with the St. Erth sands\* and this is confirmed by their position on the marine platform of Pliocene times. Before the uplift of over 400 feet which brought these deposits to something like their present position Cornwall must have consisted of an archipelago of granite islands in a shallow sea.

The former presence of other Tertiary rocks in the area is indicated by the composition of the coastal gravels. From Marazion to Mullion on the south coast the beach gravels contain a certain proportion of flint and chert pebbles, which reaches a maximum in the neighbourhood of Gunwalloe; there the composition of the gravels was found by Mr. Clement Reid† to be as follows:—

|                 |     |     |              |
|-----------------|-----|-----|--------------|
| Chalk Flint     | ... | ... | 86 per cent. |
| Greensand Chert | ... | 2   | „            |
| Quartz          | ... | 9   | „            |
| Grit            | ... | 2.5 | „            |
| Serpentine      | ... | 0.5 | „            |

There is another occurrence of flint at Ludgvan near Penzance, where on the landward side of Marazion Marsh pits have been sunk in a gravel largely composed of flint

\* Milner. Quart. Jour. Geol. Soc., 1922.

† Geol. Surv. Memoir, Lizard and Meneage, Sheet 359, 1912.



pebbles up to two or three pounds in weight\* which have the characters of pebbles derived from the Cretaceous through an Eocene gravel. These occurrences have given rise to the suggestion that an Eocene outlier exists out to sea off St. Michael's Mount. This may be connected with the occurrence of phonolite at the Wolf Rock, seven miles south of Land's End, which is probably a Tertiary intrusion belonging to the N.W. Europe petrographical province.

\* C. Reid. Quart. Jour. Geol. Soc., 1904.

## CHAPTER XII.

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### THE PLEISTOCENE AND LATER DEPOSITS.

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After the elevation of the Cornish area which took place in Pliocene times there were a series of later elevations during the Pleistocene period which had two results. They gave rise to a series of raised beaches, of which remnants now fringe part of the coast, and by stimulating the flow of the rivers they sluiced the river gravels with the result that the heavy minerals were concentrated in the lower gravels and thus the alluvial tin deposits were formed. As a result of the Pliocene uplift alluvial tin deposits were also formed at a high level so that we find high level gravels at about 400 feet above sea level such as those on the Goss Moors, and low level gravels in the river valleys such as those of Carnon Valley, St. Erth Valley, etc. In recent geological times there succeeded a depression of the area which, while not sufficient in extent to submerge the raised beaches, depressed the river valleys and gave them their present fiord-like character.

Another deposit which has its origin in the Pleistocene period is the Head, a deposit of loam and sand containing angular fragments of the local rocks which partially fills up the valleys and is seen in the cliffs of small bays to have a thickness of 20 to 50 feet. The cause of this deposit appears to be the melting of the snow and ice of the district in glacial times when Cornwall must have had an Arctic climate, though the country was not subjected to glacial action except perhaps locally on the higher land.



We also find occasional erratic boulders along the Cornish coast and on the mainland which may have been transported by floating ice or have slid to lower levels on a frozen surface. Again, there is the blown sand which covers long stretches along the coast, and the submerged forests which so frequently occur along the foreshores.

The deposits to be discussed are therefore :—

Raised Beaches and alluvial tin deposits.

Head and erratics.

Blown sand.

Submerged forests.

The raised beaches of Pleistocene times occur at different levels, varying from high water mark to 65 feet above mean sea level: where the land is high and the rocks hard the raised beach is represented by a slight notch, but where the slope of the ground is gentle the beach forms a wide shelf bounded inland by a sharp rise. The first type is illustrated by the narrow platform carrying the road from Newlyn to Mousehole, the second by the Hayle estuary where the old cliff is some way inland. Some of the most interesting exposures of the raised beach are as follows :—

Penlee Quarry, Mousehole.—Here in the left-hand side of the entrance to the quarry the beach deposit is seen on a water-worn bed of greenstone at 65 feet above ordnance datum.

St. Loy, St. Buryan.—On a platform of granite varying in level from 5 to 20 feet above high water mark there is from two to three feet of raised beach with 10 feet or more of head above.

Godrevy, Gwithian.—Here the raised beach rests on a platform of slate about three feet above high water mark. The remains of the slate platform stretch some distance seawards. The raised beach material consists of pebbles of local rocks with greenstone and chalk flint and the basal



10 inches of the material is cemented by a mixture of iron and manganese oxide which carries gold. At one point a large boulder of greenstone stands on the beach platform though there is no outcrop of this rock nearer than St. Ives. At the north end of the bay the blown sand has been cemented to a hard rock by solution and reprecipitation of the shell fragments; an outlier of this cemented sand lies on the slate platform 30 yards seaward.

Gerrans Bay, Pendower.—The beach which extends along the coast for over a mile rests on a slate platform a few feet above high water mark. It is cemented by iron oxide and the pebbles are chiefly quartz and slate.

Fistral Bay, Newquay.—At from 5 to 10 feet above the beach level the slate platform carries a pebble beach which has yielded recognisable shells (*Modiola vulgaris*, *Cytherea chione*, and *Ostrea patella*).\* Here again, the sand above the beach has been cemented to a hard rock and the beach pebbles include transported rocks such as granite, schorl rock, and altered slate; the similarity of the exposure to that at Godrevy is also marked by the occurrence of greenstone erratics on the beach, one at the southern end of the bay weighing about one and a half tons.

There are many other exposures of raised beach along the coast, in fact almost every sheltered bay shows some traces of beach deposit, but those quoted above are some of the most interesting examples. The Bodmin Moor district shows evidence of the existence of two other sea level platforms above the Pliocene shelf at heights of 750 feet and 1,000 feet above mean sea level. There is at present no data on which to date the age of these platforms.

The alluvial tin gravels as previously noted occur at two levels, the high-level gravels on the Pliocene platform and the low-level gravels in the valleys. One of the best

\* Pattison, Trans. R.G.S.C., Vol. VII.



examples of the first type is the alluvium of the Goss Moor, which, though it has been extensively worked in the past, is still the scene of dredging operations. This area, lying 400-500 feet above sea level, represents what must have been a river estuary before the Pliocene uplift. The tin-bearing gravels lie on a granite floor which has been cut into channels and hollows, and the productive gravels are confined to the lower beds, the total depth of gravel being 50 feet. In the hollows and channels the gravels may contain several per cent. of black tin.

The extraction of tin from the low level alluvials is practically a thing of the past and it is remarkable to see the way in which practically every valley in the mineral areas has been pitted and turned over. The tin-bearing gravels always lie on the bed rock, the concentration of the heavy minerals in the basal gravels being due to sluicing caused by the Pleistocene uplifts and the melting of snow on the highlands in Glacial times. In many instances the gravels of the lower valleys extend below sea level; the result of land subsidence. A typical section of the alluvial is that at Carnon Valley as given by Henwood.\*

|                                                                                        |     |     |     |     | ft.   | ins. |
|----------------------------------------------------------------------------------------|-----|-----|-----|-----|-------|------|
| Sand and mud, riverwards                                                               | ... | ... |     |     | 3     | 0    |
| Silt and shells                                                                        | ... | ... | ... | ... | 10    |      |
| Sand and shells                                                                        | ... | ... | ... | ... | 2     | 0    |
| Silt                                                                                   | ... | ... | ... | ... | 12    | 0    |
| Sand and shells                                                                        | ... | ... | ... | ... | 4     | 0    |
| Silt with many shells                                                                  | ... | ... | ... |     | 12    | 0    |
| Silt with stones                                                                       | ... | ... | ... |     | 18-22 | 0    |
| Wood, leaves, nuts, animal remains                                                     | ... |     |     |     | 1     | 6    |
| Tin ground: quartz, schorl rock, slate<br>granite and quartz with cassiterite<br>up to | ... | ... | ... | ... | 12    | 0    |

the surface at this point being 30 feet above sea level. At Pentewan human skulls were found at a depth of 40 feet,

\* Trans. R.G.S.C., Vol. IV.



mixed with remains of deer, etc. These remains can be seen in the museum of the Royal Geological Society, Penzance.

At the present time the streams to the sea carry waste from the mining districts which contains cassiterite in a very fine state of division. This is extracted at the stream works which follow one another down the valleys draining the mining districts.

The Head is best seen on the coast where the land slopes gently where it often forms a cliff 30 or 40 feet high. Inland it is difficult to distinguish head from subsoil, into which it passes imperceptibly. It attains considerable thickness in the valley bottoms and on hill slopes. For instance, it lies on a slope of  $1^{\circ}$  or  $2^{\circ}$  on the north side of Carn Brea below the granite outcrop and contains blocks of granite four or five feet in diameter. This cannot be accounted for by ordinary soil creep but is probably due to the material sliding over snow-covered slopes. We find a similar feature in Penponds Valley, where on the flat floor of the valley large blocks of greenstone, many tons in weight, were formerly scattered thickly. Many blocks have now been broken up but sufficient remain to show that they could not have reached their present positions by water action or by rolling.

Erratic blocks also occur on the coast at several points. The erratics of Godrevy and Fistral Bay have already been mentioned. Others occur on the foreshore at Porthleven, one being 50 tons in weight and composed of microcline gneiss of a type unknown in Britain; it must have been transported by floating ice. Many smaller erratics occur on the same foreshore. Along the shores of the Camel raised beaches occur which contain many transported stones, chiefly of the Staddon grit.

The blown sand occurs at many points along the Cornish coast, chiefly where a gently-sloping foreshore faces west. The most notable dune-covered areas are



Gunwalloe, Sennen, Hayle, Perranporth, and Padstow. The dunes or "towans" as they are called form desert-like country, and though the drift of the sand has been greatly checked by planting "Morrab Grass," there are barren places where all the phenomena of dune formation can be observed. The sand is often composed of shell fragments to the extent of 50 or 60 per cent. of the whole and it is to this that its extreme mobility is due. At Hayle it has been shown that the sand is 200 feet deep in places, but this is probably an exceptional depth. It often attains a height of 250 feet above sea level by covering rises in the underlying slate. The dunes carry a stunted type of flora except in the damp areas where vegetation is more normal. It is interesting to note the prevalence on the dunes of lime-loving plants which are rare elsewhere in Cornwall. The Perranporth towans contain the remains of two ancient chapels, one having been built on higher ground when the lower one was covered by the sand. Near the higher of the two there is an outcrop of greenstone carrying axinite, garnet and epidote which gives an interesting clue to the rocks now buried, while in wind-swept hollows the sand is sometimes cleared from the old soil on which the dunes were piled.

The submerged forest can be seen here and there all round the Cornish coast. One of the best exposures is the foreshore to the south of the railway station at Penzance, where stumps and trunks of trees can at low spring tide be seen among the sands of the foreshore. The low-lying land north of the railway on the east of Penzance is also the site of a submerged forest. Here, when an attempt was made to work alluvial tin years ago, the great obstacle was the occurrence of snags of timber below surface.

The occurrence of human skulls in the submerged river gravels mentioned above suggests that the subsidence which drowned the river estuaries and formed the submerged forests is of recent geological date: what that date is,



however, is another matter, and one must be content with the fact that the submergence took place during recent geological times and was, in all probability the cause of the separation of the Scilly Islands from the mainland.

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### LOCALITIES OF GEOLOGICAL INTEREST.

These localities are given under headings indicating the general character of the exposure.

#### **Lizard Rocks.**

*Polurrian Cove.* Veryan series on north side; Lizard fault on south side with hornblende gneiss.

*Porth Mellin or Mullion Cove.* Quarries at turning to Mullion Hotel show hornblende gneiss on north of valley and serpentine with granite intrusions on south. Contact of hornblende gneiss and serpentine on south side of harbour. Mullion Island can be reached in calm weather, where spilite forms the highest point of the island, with radiolarian cherts below.

*Gew Graze.* One mile north of Kynance Cove shows granite vein in serpentine, with pseudophite.

*Kynance Cove.* On north side of cove the cliffs of tremolite serpentine are invaded by granite. On south side the bastite serpentine appears and there are gabbro dykes.

*Venton Hill Point.* Epidiorite penetrating andalusite mica schist.

*Pistil Ogo and Lifeboat Coves, Lizard Point.* Cliffs showing mica schist, green schist, hornblende gneiss and granulite.

*Church Cove.* Hornblende gneiss on south with bastite serpentine on north. The Balk, on north side of cove, is noted for its well-coloured serpentine. Parn Voose Cove below the Balk shows Kennack gneiss with flaser gabbro and granite veins.



**Veryan Series.**

In addition to exposures at Polurrian Cove and Porthallow:

*Kiberick Cove.* Belcw Penare Wallas, Veryan. Cliffs show Veryan series with serpentine at north end of cove.

*Manaccan.* The bank on the west of the road below the church shows an exposure of granophyre.

*Carne.* *Veryan.* Quarries in Veryan quartzite.

*Porthluney Cove.* *Caerhayes Castle.* Veryan series with volcanics along cliffs.

**Palæozoic Slates ("Killas").**

*Porthleven.* Cliffs east and west of Porthleven show slates, often folded, with greenstone sills on east.

*Godrevy.* Cliffs opposite lighthouse visited at low tide, show folding in slates, also alternation of slates and grits.

*Pendennis Point, Falmouth.* Good slate exposures on foreshore.

**Devonian Beds.**

*Ladock Quarry.* Seven miles north of Truro on Bodmin Road. Grampound grit.

*Watergate Bay.* Devonian slate with fish remains.

*Fowey.* Cliffs from Fowey East show Devonian beds, often fossiliferous.

*Lostwithiel.* Quarries to east show Meadfoot beds.

*Bodmin.* Second milestone on road to Bodmin Road. Quarries show Staddon grit.

*Delabole.* Quarries for roofing slate.

**Culm Measures.**

*Pillaton Church.* Half a mile to west is a quarry showing Culm Measure cherts.

*Halonquay.* Along shore of Tamar Lower Culm Measures are exposed for 400 yards.

### **Basic Igneous Rocks.**

*Porthleven.* Sills of ophitic greenstone on foreshore to east of harbour.

*Gurnard's Head.* Headland due to sills of greenstone dipping seawards.

*Tuckingmill, Camborne.* Quarry by gas works shows fine-grained epidiorite.

*Rock, opposite Padstow.* Quarry by ferry shows proterobase with adinole at contact with slate.

*St. Minver.* Quarry shows proterobase.

*Treglennick, St. Merryn.* A quartz diabase occurs.

*St. Breward.* All basic rocks to north are epidiorites too tough to quarry.

*Menheniot.* Quarry south side of station in picrite. Also at Clicker Tor above quarry.

*Pentire Head.* Headland composed of spilitic pillow lavas.

### **Granite.**

*Sheffield Quarries.* One mile from Newlyn, on road to Lamorna. Granite with large feldspars, segregations, pinite and slate xenoliths.

*Newmill Quarry.* Three miles from Penzance on road to Gurnard's Head. Granite with flow structure and pinite.

*Castle Inch.* Above Ludgvan. Quarries show fine-grained granite with pinite and pinitiferous pegmatite.

*Knill's Monument, St. Ives.* Quarries on north side show fine-grained granite with topaz and andalusite.

*Long Downs.* Five miles from Falmouth towards Helston. Many quarries in well-jointed granite free from mineralisation.



In several quarries veins of pegmatite occur with vughs showing good crystals of orthoclase, quartz, gilbertite mica and apatite.

*St. Breward.* Quarry in fresh unaltered granite, slightly foliated.

*St. Agnes Beacon.* A new quarry has been opened above the sand pits on the north west side of the Beacon showing fine grained granite with phenocrysts of both quartz and felspar. Near the coastguard look-out on the cliff a quarry shows quartz porphyry which is kaolinised along mineral veins.

*Carn Brea, Redruth.* Granite with tors and aplite veins.

*Carn Marth.* Harvey's Quarry on north-west side of hill shows three types of granite:—

1. Coarse grained granite.
2. Fine grained granite.
3. Fine grained granite with tourmaline.

*Ponsanooth Quarry.* Foliated granite with aplite, pegmatite and quartz porphyry.

*Wheal Coates.* North west side of St. Agnes Beacon. Granite with texture of quartz porphyry.

*Delank Quarry.* North of Bodmin. Coarse grained granite with apophysis of fine grained granite.

*Gready Quarry, Luxulyan.* Quarry in unmineralised granite with pegmatite.

### **Aplite.**

See Carn Brea, p. 95, and Ponsanooth Above.

*Carn Marth.* Quarry above Carharrack shows aplite in granite.

### **Pegmatite.**

See Ponsanooth, above. Castle Inch. Gready. Megilligar Rocks. One and a half miles west of Porthleven.

Veins of pegmatite and aplite with slate xenoliths.

*Trelavour Downs, St. Dennis.* Vein of banded pegmatite with coarse felspar and lithia mica.

*Tresayes Downs, Roche.* Dyke of very coarsely crystallised pegmatite.

### **Quartz Porphyry (Elvan).**

*Sennen Common.* Quarry on south of main road to Land's End shows silicified and tourmalinised quartz porphyry.

*Treglistian.* About one mile south of Copperhouse, Hayle. Quarry in quartz porphyry which carries graphite.

*Praa Sands.* Quartz porphyry dyke outcrops on fore-shore at west end of beach. It is highly porphyritic and contains pinite.

*Hangman's Barrow.* Above Nine Maidens,  $6\frac{1}{2}$  miles Redruth side of Helston. Quarry showing microgranite in granite. Chilled margin with flow structure. Graphite occurs in elvan.

*Brea, Tuckingmill.* Quarry just south of railway bridge. Granophyre dyke in granite.

*Carn Brea.* North slope of hill and quarry at east end. Highly porphyritic dyke of granite porphyry with well-marked chilled margin.

*Saveock Water.* Quarry on south side of road near fourth milestone from Truro to Redruth. Dyke of granite porphyry with tourmaline and pyrite.

*St. Agnes.* On top of cliff quarter mile west of Trevaunance Cove. Quarry in granite porphyry with kaolinised felspar.

*Tremore Bridge, Withiel.* Quarry in granite porphyry with tourmaline.

*Parbola Mine, Wall, Gwinear.* Dyke of quartz porphyry with cassiterite.



*Copper Hill, Troon.* A new quarry called Holman's upper quarry, shows a fresh granite porphyry.

These are only a few of the more interesting exposures of quartz porphyry; they are very numerous and widely scattered.

### **Mica Trap.**

*Helford Passage.* On north foreshore, quarter mile west of ferry. Outcrop of mica trap on beach and in cliff.

*Trelissick, River Fal.* Opposite Turnaware Point. Mica trap sill outcrops in low cliff.

*Headland and North Side of Gannel, Newquay.* Dykes of mica trap at several points.

### **Contact Metamorphism.**

*Porthmeor Cove.* South-west of Gurnard's Head. Cove should be approached on north side of stream. Cliff shows veins of granite and pegmatite in tourmalinised slate.

*Pendour Cove.* Third cove north of Gurnard's Head. Veins of granite in slate and greenstone, mixed magma rock, lode outcrops.

*Wicca Pool.* One and a half miles north of Zennor. Granite and pegmatite veins in altered slate.

*Tater Du.* One mile west of Lamorna Cove (west side of headland). Veins of granite in greenstone and altered slate.

*Gurnard's Head.* Andalusite schist occurs below sill of greenstone on headland, also spilosite.

*Trevaylour Quarry.* One and a half miles towards Gurnard's Head from Penzance. Quarry is concealed and is approached by a white gate. Spotted and bleached greenstone.

*Camelford.* Above the park on the east. Quarry in calc-flinta with epidote, garnet, axinite and arsenopyrite.

Above the park on the west. Quarry in andalusite slate:

*Trebarwith Strand.* The cliffs show highly micaceous slates with lenticles of calcite. A little way up the valley is a good escapement of calcareous volcanic tuff. (Schalstein).

*St. Ives.* North side of "Island." Adinole occurs along contact of greenstone and slate.

*Wheal Coates.* In old openwork granite and tin veins penetrate slate with chialtolite.

*Ponsanooth.* Railway embankment and cutting towards Falmouth. Knotted slate with andalusite and tourmaline; mica schist.

The waste heaps at the three new shafts at Roskear, East Pool and Agar, and Tolgus Mines, between Camborne and Redruth, show all types of altered slate and greenstone.

### **Tourmaline Granite and Schorl Rock.**

*Trevalgan Farm.* Two miles west of St. Ives. Walls in this area show blocks of trevalganite, a partially or completely tourmalinised granite with large feldspars.

*Luxulyan Valley.* Above aqueduct. Scattered blocks of luxulyanite.

*Botallack Mine.* Waste heaps show many types of tourmaline granite.

*Wheal Louisa Clay Pit, Burngullow.* Tourmaline granite with gilbertite after feldspar.

*St. Mewan Beacon, Burngullow.* Schorl rock with topaz.

*Roche.* Prominent outcrop (Roche Rock) of schorl rock.

*William's Shaft, Pengegon, Camborne.* Waste heap shows "capel" (blue-grey quartz tourmaline rock) and "peach" (quartz chlorite rock).



Almost every clay pit and waste heap in the granite area shows various types of tourmaline granite and schorl rock; also greisen and other altered granites.

### **Greisen.**

*St. Michael's Mount.* The southern foreshore shows veins of greisen with metallic minerals. (Permission to visit must be obtained).

*Cligga Head, Perranporth.* Similar exposure to that at St. Michael's Mount. (Permission to visit must be obtained from Messrs. Nobel, Perranporth).

*Belowda Beacon, north of Goss Moor.* Veins of greisen and topaz-fels in granite on north slope of hill to east of road.

### **Calc Flinta and Axinite.**

*Carrick Du Quarry, St. Ives.* Veins of axinite, zoisite, actinolite, etc., in greenstone.

*Cliff south of Levant Mine.* Massive axinite and garnet as well as veins in greenstone; hornblende, actinolite and epidote.

*St. Columb Road.* Quarry at Killaworrey, one mile towards St. Columb Major. Calc-flinta with axinite, garnet and epidote.

*Tremore Bridge.* Calc-flinta similar to above.

### **Tourmaline Slate.**

See *Wicca Pool*, p. 94. *Porthmeor Cove*, p. 94.

*Wheal Fortune.* Waste heaps above mine show beautifully laminated tourmaline slate.

*Gwennap United Mines, St. Day.* Waste heaps show tourmaline slate with native copper, chalcocite and malachite.

**China Stone.**

*Tregargus Quarry, St. Stephens.* China stone with much fluor and gilbertite.

*St. Dennis to Nanpean.* China stone in most clay pits.

*Parc an Chy Mine, St. Day.* Granite with fluor, gilbertite and cassiterite.

**China Clay Rock.**

All over the western half of the St. Austell granite the china clay pits are very numerous. They can be reached from St. Austell, Burngullow, St. Stephens, St. Dennis or Roche. Pits also occur at Balleswidden, near St. Just, and Towednack, near St. Ives.

**Lode Outcrops.**

*St. Agnes.* Excellent lode outcrops in the cliffs of Trevaunance Cove and Trevellas Porth. They must be visited at low tide.

*Perranporth.* Great Perran Iron Lode outcrops at north end of bay. A good lode outcrops at north end of cliffs in the middle of the bay.

*Pendour Cove,* see p. 94.

*Mulberry Mine.* One mile and a half north-west of Lanivet. Open-work in stockwork of tin veins in slate. Approach on north-west side.

*Wheal Fortune.* Half a mile west of Sithney. Old openwork in stockwork of tin veins in tourmalinised slate. Approach from bottom end of lower pit.

*Magdalen Mine, Ponsanooth.* Openwork in stockwork of tin veins in slate and greenstone.

*Porthleven.* On the east of the harbour in the last projecting cliff towards Looe Bar. A copper lode outcrop in which the sulphides have been largely oxidized to sulphates.



*Cadgwith.* The Devil's Fryingpan lies on the south side of the cove: dunite serpentine, hornblende gneiss and Kennack gneiss are to be seen in the walls of the hollow.

*Kennack Sands.* To the south of the gate, cliffs of bastite serpentine are cut by veins of granite, gabbro and epidiorite, with Kennack gneiss beyond. Asbestos occurs here and in the centre of the bay.

*Carrick Luz and Sperrick Cove.* Descend cliff just south of landslip. Pale gabbro gneiss and flaser gabbro.

*Black Head.* Numerous dykes of dolerite and epidiorite.

*Coverack.* Foreshore below post office shows troctolite and gabbro cutting serpentine. Troctolite also occurs in Perprean Cove.

*Porthallow.* Cove shows Lizard fault and foliated serpentine. Nelly's Cove on the north shows Veryan series with limestone outcrops on foreshore. At Penare, one mile north of cove there is a prominent outcrop of Veryan quartzite. Along the coast is a well marked raised beach platform and fossils may be found in the Veryan beds.

*Crousa Common.* At ninth milestone from Helston on the St. Keverne road. Beds of Pliocene gravel lying on gabbro.

*Tresize.* On Helston-Manaccan road. Quarry in dunite serpentine.

*Goonhilly Downs.* Sixth milestone from Helston to Lizard. Pits in granite invading serpentine.

*Bonython.* Bottom of valley half a mile south of Cury Cross. Quarry in hornblende gneiss.

### **Pliocene Deposits.**

*St. Erth.* Pits by vicarage. Beds of sand and clay with fossils.

*Polcrebo Downs, Nancegollan.* Beds of quartz gravel on decomposed granite.

*Crousa Common, St. Keverne.* Beds of quartz gravel on gabbro.

*St. Agnes.* A semicircular outcrop of sands and clays from Wheal Coates round north of Beacon to east side.

### **Cornish Museums.**

Cornwall is exceptionally rich in museums containing good collections of minerals and geological specimens. The museum of the Royal Geological Society of Cornwall in the west wing of St. John's Hall, Penzance, is the only purely geological museum. It contains excellent collections of minerals and rocks, a fine collection of type fossils, and the best collection of Cornish fossils extant. The library contains works dealing with Cornish geology and the Transactions of the Society go back to 1813.

The School of Metalliferous Mining, Camborne, contains a fine collection of minerals and a collection of Cornish rocks. It is open to the public. There is also a collection of Cornish flint implements in the Camborne Free Library.

The Hunt Museum, Redruth Mining School, contains a good collection of Cornish minerals.

The Museum of the Royal Institution of Cornwall, River Street, Truro, is largely concerned with historical, antiquarian and natural history subjects, but there is a mineral collection in course of preparation which contains some fine specimens.



## CORNISH MINES.

|                                       | <i>Country Rock.</i>                            | <i>Minerals.</i>                                                                                         |
|---------------------------------------|-------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Lambriggan Mine,<br>Ferranporth.      | Devonian<br>Slate                               | Galena, Zinc Blende,<br>Pyrites, Quartz.                                                                 |
| South Terras Mine,<br>Grampound Road. | Devonian<br>Slate and<br>Quartz porphyry        | Pitchblende,<br>Torbernite,<br>Autunite<br>Cobaltite<br>Arsenopyrite<br>Chalcedony<br>Quartz             |
| Wheal Kitty,<br>St. Agnes.            | Devonian<br>Slate                               | Cassiterite<br>Arsenopyrite<br>Pyrites, Quartz,<br>Chlorite                                              |
| Levant Mine<br>Pendeen.               | Slate and<br>Epidiorite with<br>Fegmatite veins | Chalcopyrite<br>Cassiterite<br>Arsenopyrite<br>Pyrites, Quartz,<br>Chlorite<br>Actinolite                |
| Kit Hill Mine,<br>Callington.         | Granite.                                        | Cassiterite, Wolfram,<br>Molybdenite                                                                     |
| South Crofty Mine,<br>Camborne.       | Slate and Granite                               | Cassiterite, Wolfram,<br>Arsenopyrite, Stannine,<br>Quartz, Chlorite,<br>Tourmaline.<br>As South Crofty. |
| East Pool & Agar Mine,<br>Redruth.    | Slate and<br>Granite                            |                                                                                                          |
| Polhigey Mine,<br>Carnmenellis.       | Granite                                         | Cassiterite,<br>Pyrites, Arsenopyrite,<br>Quartz, Tourmaline,<br>Chlorite                                |
| Porkellis Mine,<br>Near Wendron.      | Granite                                         | Cassiterite,<br>Tourmaline, Quartz,<br>Specular Haematite                                                |
| Geevor Mine,<br>Pendeen.              | Granite                                         | Cassiterite<br>Arsenopyrite<br>Haematite<br>Tourmaline, Quartz,                                          |

At the time of publication these mines are for the most part closed down owing to the low price of tin metal. Specimens can, however, usually be obtained on the waste heaps.

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No. 357 and 360. Scilly Isles. No. 351 and 358, Land's End.

No. 352. Camborne and Falmouth. No. 359, Lizard and Meneage.

No. 346. Newquay. No. 335. Trevoze Head.

No. 353. Mevagissey. No. 347. Bodmin and St. Austell.

No. 336. Padstow and Camelford. No. 348. Plymouth and Liskeard.

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*ABBREVIATIONS.*

- Q.J.G.S.—Quarterly Journal of the Geological Society.  
Trans. Roy. Geol. Soc. Corn.—Transactions of the Royal Geological Society of Cornwall, Penzance.  
Rep. Roy. Corn. Pol.—Annual Report of the Royal Cornwall Polytechnic Society, Falmouth.  
Trans. Corn. Inst. Eng.—Transactions of the Cornish Institute of Engineers, Camborne.  
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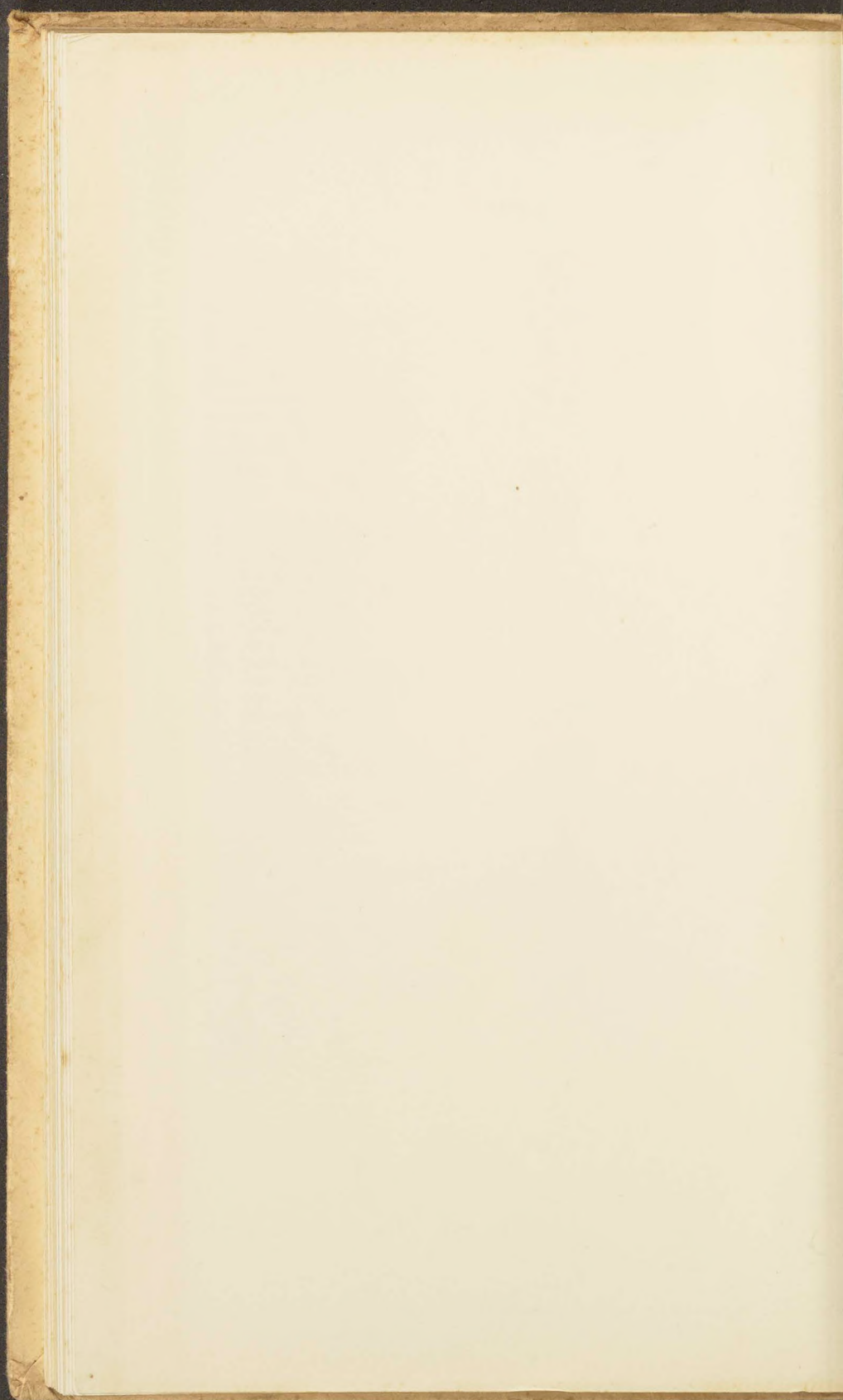
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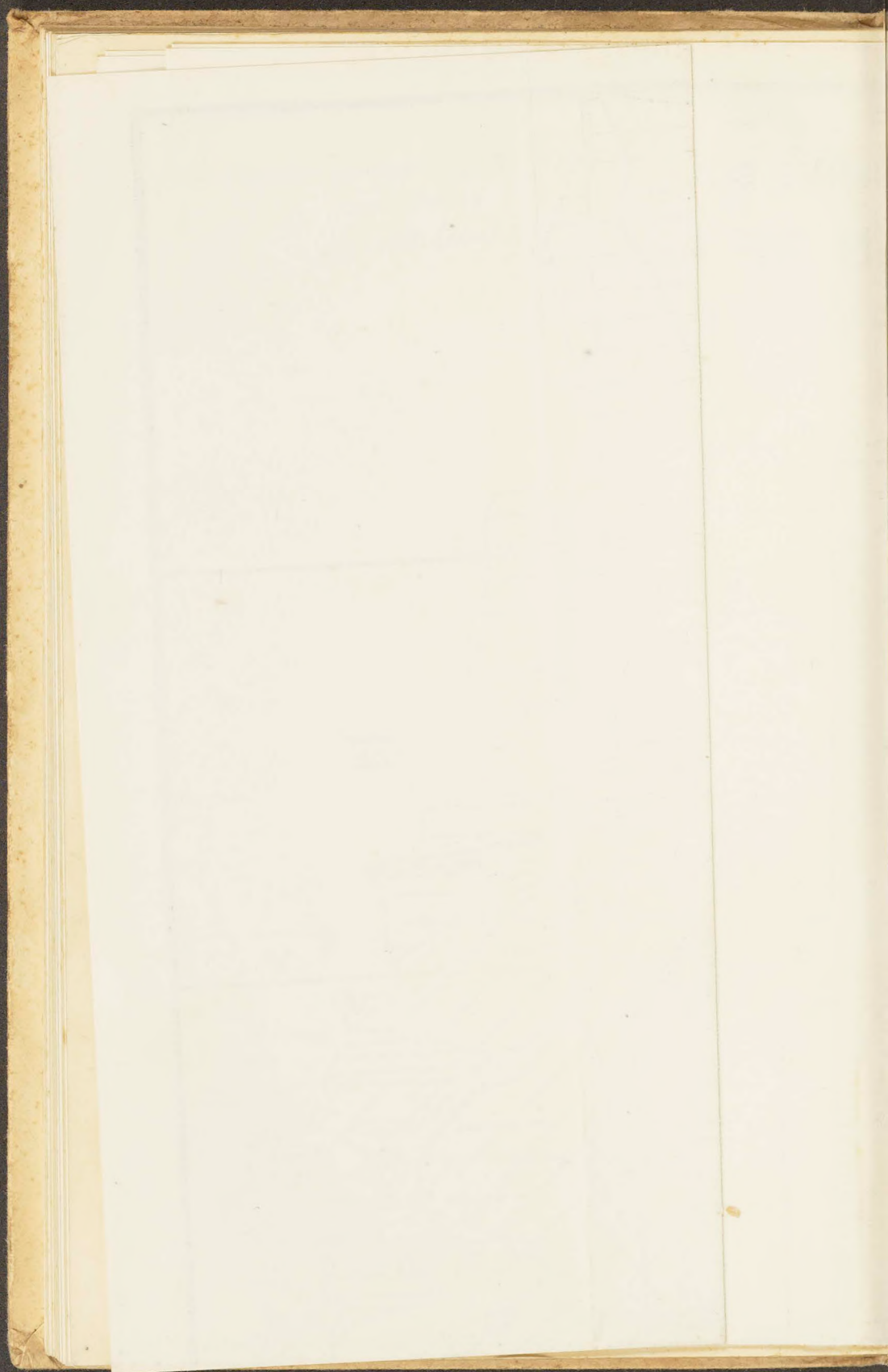














Aug 1077



**MAP SHOWING SITUATION OF  
THE MINES OF CORNWALL.  
AND GEOLOGICAL FEATURES.**

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## LEGEND

Blown Sand

Pliocene

Culm Measures

U&M Devonian

L. Devonian

Palaeozoic

Veryan S.

Q Porphyry

Granite

Volcanics

Basic Rocks

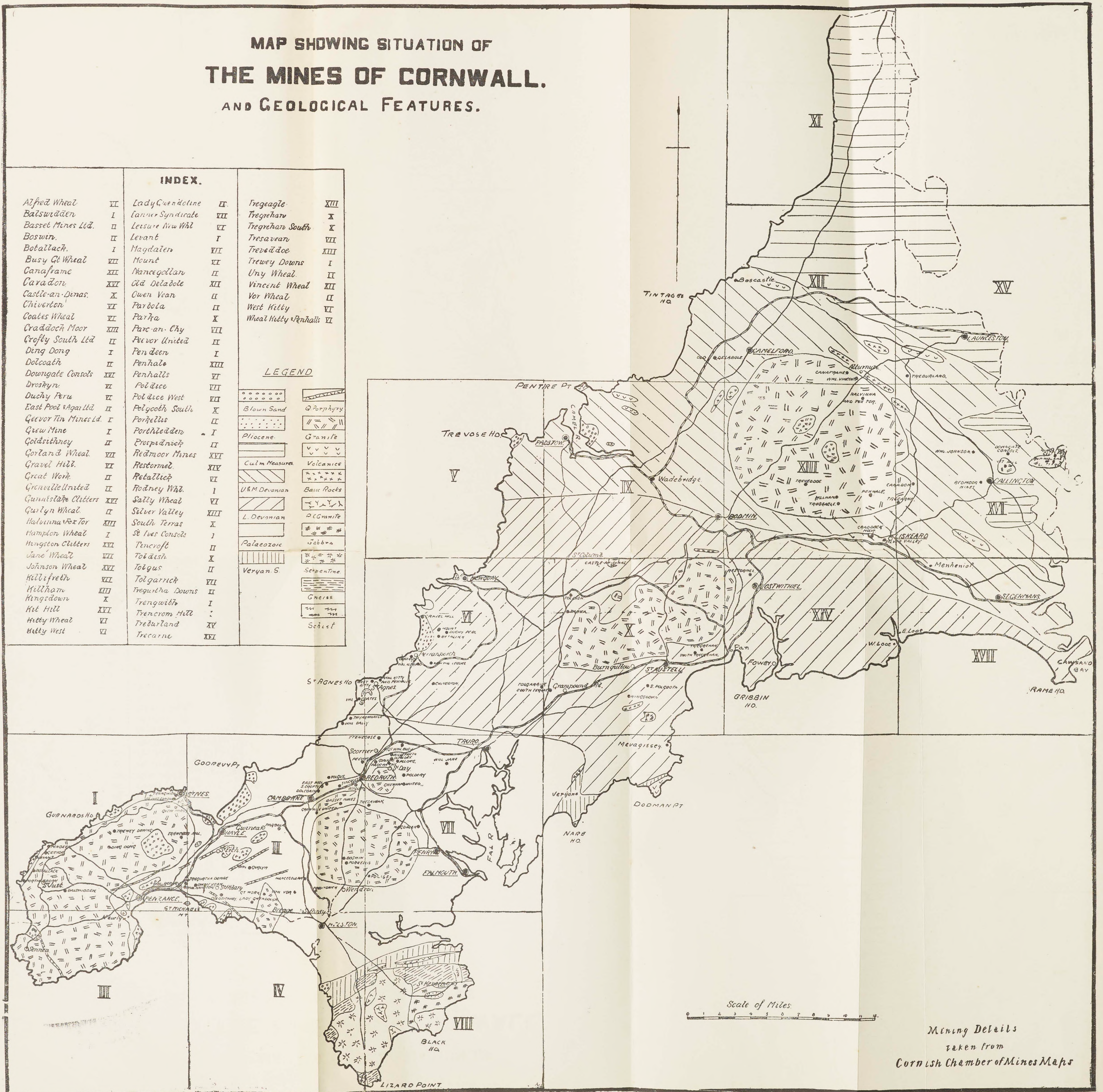
PEGranite

Gabbro

Schist

Gneiss

Schist





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